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Site Specific Water Quality Assessment: Silver Bow Creek and Clark Fork, Montana

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SITE SPECIFIC WATER QUALITY ASSESSMENT

Silver Bow Creek and Clark Fork, Montana

by

Jeffrey J. Janik and Susan M. Melancon
Department of Biological Sciences
University of Nevada, Las Vegas
Las Vegas, Nevada 89154

Cooperative Agreement No. CR808529

Wesley L. Kinney, Project Officer
Advanced Monitoring Systems Division
Environmental Monitoring Systems Laboratory
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NOTICE

This document has not been peer and administratively reviewed within EPA and is for internal Agency use and distribution only.

TABLE OF CONTENTS

TABLES

FIGURES

I. INTRODUCTION

Increasing use of metals in manufacturing and chemical industries has caused a measurable rise in ambient toxic metal concentrations in industrial discharges (Spaulding and Ogden 1968). As a result, many of our nation's receiving surface waters contain elevated levels of metals. Primary sources of most toxic metals include industrial and municipal sewage treatment plant (publicly owned treatment works) discharges, mine drainage, and atmospheric precipitation (Spaulding and Ogden 1968; U.S. EPA 1979b).

The effluent and sludge of many publicly owned treatment works (POTWs) are known to contain high metal concentrations (Dewalle and Chian 1980). This has been assumed to result from industrial wastewater discharges to POTWs. However, high metal concentrations have also been found in POTWs which do not receive industrial wastes.

Results from recent sampling of a wide spectrum of POTW effluents (U.S. Geological Survey data [WATSTOR]; Sverdrup and Parcel and Associates, Inc. 1977; Dewalle and Chian 1980) showed that the concentration of several toxic metals in receiving streams exceeded freshwater aquatic life criteria recommended by the U.S. Environmental Protection Agency (U.S. EPA 1976). In many cases, levels were of sufficient magnitude to suggest that the biological communities of many of the nation's surface waters could be experiencing severe impacts. However, undocumented reports have claimed that substantial populations of aquatic life (fish, invertebrates, plants) exist in a healthy condition in waters containing concentrations in excess of the recommended criteria.

Prompted by this apparent contradiction the EPA Office of Water Regulations and Standards (OWRS) issued a directive to document the water and biological quality that exist in selected streams receiving POTW discharges. Later, as other important sources of metals were identified, the program was expanded to include the investigation of mining and industrial discharges. The toxic metals program was based on the following study objectives:

1. To document the concentration and distribution of toxic metals in selected streams receiving discharges from publicly owned treatment works, mining, and industrial wastes.

2. To determine the biological state of selected receiving waters. This included sampling and analyzing fish, benthic invertebrates, and periphyton communities.

3. To compare ambient metal concentrations with established EPA criteria levels.

4. To develop explanatory hypotheses when healthy biota exist where criteria are exceeded.

The project was undertaken as a cooperative effort by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, Nevada (EMSL-LV), and the Environmental Research Laboratories at Corvallis, Oregon (ERL-Corvallis), and Duluth, Minnesota (ERL-Duluth). EMSL-LV designed and supervised the project; the field investigation and subsequent laboratory analyses were coordinated by personnel at the University of Nevada, Las Vegas (UNLV). Laboratories at ERL-Duluth and/or ERL-Corvallis performed static bioassay tests to assess the toxicity of whole and filtered water samples from each stream investigated.

From a list of approximately 200 candidate streams, 50 were selected for a preliminary field survey. Subsequently, the list was narrowed to 15 streams (Table 1) which receive mining, industrial, or municipal discharges. Streams were selected to provide broad geographical representation and a range of watershed characteristics and uses, pollution sources, water quality characteristics, biota, and habitats. Field sampling for biological, physical, and chemical water quality information was conducted from July 28 to November 10, 1980. Figure 1 illustrates the general approach to each study site. In each river, attempts were made to establish a control site upstream from a discharge point. Transects were established downstream from the discharge to define impact and subsequent recovery zones.

Individual study sites were ideally chosen according to the following criteria:

1. Toxic metal concentrations upstream from effluent discharges were below current water quality criteria.

2. Metal concentrations in receiving waters after complete mixing with effluent discharge were 5 to 10 times greater than the water quality criteria. In some cases however, streams known to be of high state or regional interest were selected where these selection criteria were not fully applicable.

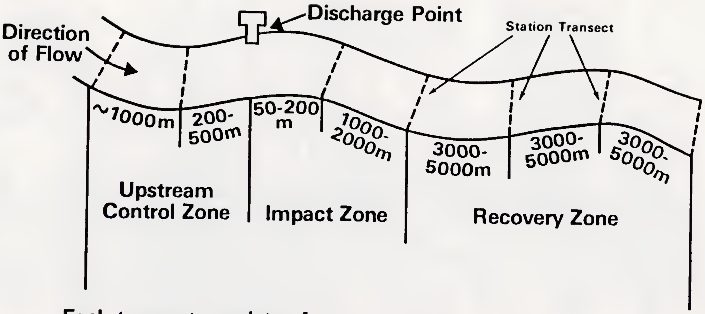
The 1980 toxic metals project was initiated by the U.S. EPA as a one-time survey of a variety of streams to examine the relationships between ambient metal concentrations, acute (never-to-be-exceeded) water quality aquatic life criteria, and resident biological communities. The survey was not intended to provide an in-depth analysis of the physical/chemical and biological dynamics of any stream sampled, but rather, to provide a general survey of the condition of aquatic biota in receiving waters where aquatic life criteria were exceeded for at least one metal. Conclusions drawn beyond those presented in this report, then, should be considered in light of these considerations.

Data from the 1980 toxic metals project will be presented in 15 separate reports discussing each river system; a summary project report will follow the individual basin studies. This report addresses data collected in Silver Bow Creek and Clark Fork, Montana.

TABLE 1. 1980 STUDY LOCATIONS, TYPES OF DISCHARGES, AND METALS ANTICIPATED TO BE PRESENT IN EXCESS OF EPA RECOMMENDED AQUATIC LIFE CRITERIA*

Pollution Source / Stream	Metal(s)
Mining	
Prickly Pear Creek, Montana	Copper, Zinc, Cadmium
Silver Bow Creek, Montana**	Copper, Cadmium, Zinc
Slate River, Colorado	Copper, Zinc, Silver, Cadmium
Tar Creek, Oklahoma	Zinc, Cadmium, Silver, Lead
Red River, New Mexico	Copper, Cadmium
Industrial	
Leon Creek, Texas	Chromium, Nickel
Little Mississinewa River, Indiana	Lead, Chromium
Public Owned Treatment Works (POTW)	
Bird Creek, Oklahoma	Arsenic, Selenium
Cedar Creek, Georgia	Chromium, Silver
Maple Creek, South Carolina	Chromium
Irwin Creek, North Carolina	Chromium, Zinc, Nickel, Lead
Blackstone River, Massachusetts	Cadmium, Lead
Mill River, Ohio	Nickel
Cayadutta Creek, New York	Chromium, Cadmium
White River, Indiana	Copper

*In most cases the acute criteria were exceeded (U.S. EPA 1976); chronic criteria were exceeded in all cases. Those metals actually exceeding criteria during the 1980 sampling year for some of the rivers may be slightly different from this initial listing.
**Also receives POTW discharge.



Each transect consists of:

5 replicates for biological samples
Electrofishing 100 meters of stream reach
3 replicates for tissue, sediment and water samples
1 twenty-four hour composite water sample
8 three hour integrated water samples
\+ 45 hydrolab measurements (9 parameters x 5 replicates)

Figure 1. Generalized diagram of the field sampling approach.

STUDY AREA

Silver Bow Creek and its tributaries originate in high mountains around Butte Valley, approximately 100 km upstream from Gregson Hot Springs. The Creek covers a drainage area of 1250 km^2 and meanders through a series of valleys before joining with Warm Springs Creek to form Clark Fork (WESTECH 1979). Mountain snowpacks provide much of the water used for agricultural, industrial, and domestic use; irrigation usage commits the most significant portion of the basin's available surface water (WESTECH 1979). The area is arid, with a mean precipitation of 29.2 cm/year (Peckham 1979). Peak flows occur during spring runoff, with low flow during late summer and winter. Although agriculture and production of forest products are the largest land uses in the study area, mining activities concentrated upstream around Butte are also of local economic significance.

Silver Bow Creek has long been used for waste material disposal from the Anaconda Company mining and mineral processing facilities (WESTECH 1979). Mine drainage, tailings, and ore milling wastewater effluents have been discharged between Butte and Gregson Hot Springs for about 100 years. These discharges made the stream unsuitable for support of aquatic life (Peckham 1979). Implementing primary and secondary treatment during 1974 at Butte, and use of treatment ponds near Warm Springs, have caused substantial water quality improvement in the river. Although the Warm Springs ponds "have a small storage capacity and have little ability to regulate streamflow" (WESTECH 1979), reduction of suspended solids and adsorbed metals in Clark Fork River downstream from the Warm Springs (Anaconda) ponds has led to reestablishment of a resident biological community (Peckham 1979).

Six stations (Figure 2) were sampled from August 3-11, 1980. There were no control zone stations because of mining activities upstream of the study area. Three impacted stations were sampled in Silver Bow Creek (026, 024, and 021), and one station (027) was sampled in the Anaconda settling ponds. Warm Springs Creek enters downstream from the Anaconda Ponds. This flow combines with channelized runoff from Silver Bow Creek which is passing through the settling ponds to form Clark Fork. Because of the improved water quality conditions in Clark Fork downstream from the ponds, two stations (023 and 025) sampled there were designated as recovery zone sites.

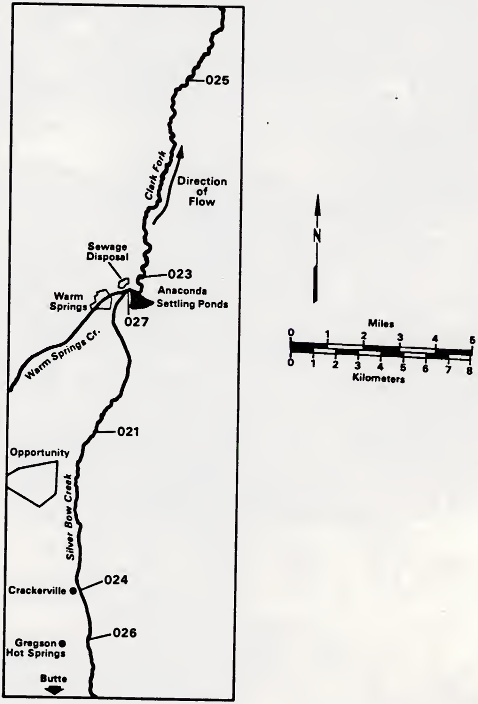


Figure 2. Station locations on Silver Bow Creek and Clark Fork, Montana.

II. METHODS

CHEMICAL

Water

Field Collection --

To determine Silver Bow Creek and Clark Fork water quality characteristics, horizontal and vertical profiles of pH, conductivity, temperature, dissolved oxygen (DO), and reduction/oxidation (redox) potential were measured at each station with a Hydrolab 4041 water quality measurement system (Table 2). Other field measurements included turbidity with a Hach nephelometer, flow with a Gurley Teledyne flow meter, and chlorine with a Hach field chlorine kit. Triplicate grab samples were collected at each site mid-depth between surface and bottom, preserved appropriately for each analysis as specified in U.S. EPA (1979c) and APHA (1980), and shipped to EMSL-LV for analysis (Table 3). Grab samples were filtered on site (0.45 μm filter) to separate total and dissolved metal fractions. All grab samples were acidified with Ultrex nitric acid to a pH of <2.0 and shipped to UCLA's Laboratory of Biomedical and Environmental Science for ICP analysis. In addition to manual grabs, an ISCO sampler collected 24-hour composite samples at one-hour intervals for metal analyses. Three one-hour samples of 100 ml each were composited in a 450 ml sample vessel; thus, eight three-hour composite samples were collected at each station. Samples were acidified with Ultrex nitric acid and shipped to UCLA for ICP analysis.

Laboratory Analysis --

Tables 4, 5, and 6 provide precision, accuracy, and range or detection limit information on analytical methods used for laboratory analyses of water quality in Silver Bow Creek and Clark Fork.

Sediments

Field Collection --

Streambed sediments were collected from both Silver Bow Creek and Clark Fork to determine the extent to which metals entering from the various discharges accumulate in sediments. When available, backwater pool areas were sampled. Sediment cores were collected with a WILDCO 5 cm brass core sampler fitted with a plastic core liner and eggshell core catcher. A series of core samples were collected from the submerged root zone along a stream bank. When necessary, several shallow core samples were collected to fill one core tube replicate. Three replicate core samples were collected from every station except 023 in Clark Fork and shipped to EMSL-LV.

TABLE 2. HYDROLAB DIGITAL 4041 WATER QUALITY MEASUREMENT SYSTEMS SPECIFICATIONS

A. Temperature System:	
Method:	linear thermistor
Range:	(-5 to +45)°C
Resolution:	0.1°C
Accuracy (overall):	+0.2°C
Precision:	(1)
Calibration:	factory calibrated (NBS traceability)
*Response time (nominal):	2.5 sec.
8. pH System:	
Method:	glass electrode (sealed Ag/AgCl reference)
Range:	0 to 14 pH
Resolution:	0.1 pH
Accuracy (overall):	+0.1 pH (over 3 pH interval)
Precision:	(1)
Calibration & Slope:	customer calibrated against buffer standards of good quality
C. Conductivity:	
Methods:	four-electrode cell, temperature compensated (reference: 25°C)
Range (3):	(0-2K), (0-20K), (0-200K) μmhos/cm
Resolution:	0.05% or range selected
Accuracy (overall):	+1.0% or range selected
Precision	(1) instructions are provided for taking into account second-order variations in natural water conductivity-temperature coefficients.
*Response time (nominal):	negligible to conductivity change; 2.5 sec. for temperature change customer calibrated in freshly prepared KCL standards
D. Dissolved Oxygen:	
Method:	membrane covered, gold/silver polarographic cell
Range:	(0-20) mg/l
Resolution:	0.1 mg/l
Accuracy:	+0.2 mg/l
Precision:	(1)
Calibration:	customer calibrated in atmospheric air, or saturated water
*Response time (nominal):	12 sec. at 20°C

Note: The Circulator accessory should be employed at any time there is reason to suspect that there is insufficient natural circulation to maintain a stable dissolved oxygen measurement.

* Time required for 63% response to step change is variable.

(1) Precision has not been field tested, the actual coefficient of variation is expected to be within 10%

Source: Hydrolab Corporation, Austin, Texas. Bul. No. 4041-8180.

TABLE 3. VOLUME OF WATER SAMPLES COLLECTED DURING 1980 FROM EACH STATION, SAMPLE TREATMENT, AND PARAMETERS MEASURED. All samples were collected in triplicate during each sampling period.

Parameter	Sample Volume	Preservative
	Nonfiltered	
Cyanide (CN)	16OZ	Ice
Total Organic Carbon (TOC)	4OZ	H_2SO_4
Residues	16OZ	Ice
Total Filterable Nonfilterable		
Alkalinity	16OZ	Ice
Nutrients	4OZ	H_2SO_4
Phosphorus, hydrolyzable (P-hydro) Ammonia (NH_3-N) Kjeldahl-N (KJEL-N)		
Metals, Total	4OZ	HNO_3
	Filtered (0.45μ)	
Nutrients	4OZ	H_2SO_4
Nitrate-Nitrites (NO_3-NO_2-N) Orthophosphate, Dissolved (P-D, Ortho)	4OZ	Ice
Metals, Dissolved	4OZ	HNO_3

TABLE 4. LABORATORY METHODS, PRECISION, ACCURACY, AND RANGE FOR NUTRIENT AND ALKALINITY ANALYSES USING TECHNICON AUTO ANALYZER

Parameter	STORET No.	Reference Method	Precision As Std. Dev. (mg/l)	Accuracy as Bias (%)	Accuracy as Bias (mg/l)	Range (mg/l)
Total Orthophosphate (P. Ortho)	70507	USEPA (1979c) 365.1	0.014[1] 0.087 0.066	-8.3[1] -15.5 -12.8	-0.003[1] -0.05 -0.04	
Hydrolyzable Phosphorus Total (P. Hydro)	00669	USEPA (1979c) 351.1				
Total Kjeldahl Nitrogen (TKN)	00625	USEPA (1979c) 351.1	0.54[2] 0.61 1.25 1.85	-24.6[2] -28.3 -23.8 -21.9	-0.46[2] -0.62 -1.21 -1.27	0.05-2.0
	00625	USEPA (1979c) 351.2	±0.07[3] ±0.03 ±0.15	99% recovery[4] 99% recovery		0.1-20.0
Ammonia Nitrogen (NH_3-N) Total	00610	USEPA (1979c) 350.1	±0.005[5]	107% recovery[6] 99% recovery		0.01-2.0
Nitrate-Nitrite Nitrogen (NO_3-NO_2-N)	00630	USEPA (1979c) 353.2	0.012[7] 0.092 0.318 0.176	+5.75[7] +18.10 +4.47 -2.69	+0.017[7] +0.063 +0.103 -0.067	0.05-10.0
Alkalinity	00410	USEPA (1979c) 310.2	±0.5[8]	100% recovery[9] 99% recovery		10-200

[1]Precision, accuracy, and range apply to all phosphorus forms. Precision and accuracy based on results of six EPA laboratories using four natural water samples containing increments of orthophosphate of 0.04, 0.04, 0.29 and 0.30 mg/l (USEPA 1979c).

[2]Based on results of six EPA laboratories using four natural water samples containing increments of organic nitrogen of 1.89, 2.18, 5.09 and 5.81 mg/l (USEPA 1979c).

[3]Based on EMSL-CIN test using sewage samples of concentrations of 1.2, 2.6 and 1.7 mg N/l (USEPA 1979c).

[4]Based on EMSL-CIN test using sewage samples of concentrations of 4.7 and 8.74 mg N/l (USEPA 1979c).

[5]Based on EMSL-CIN test of surface waters at concentrations of 1.41, 0.77, 0.59 and 0.43 mg NH_3-N/l (USEPA 1979c).

[6]Based on EMSL-CIN test of surface waters at concentrations of 0.16 and 1.44 mg NH_3-N/l (USEPA 1979c).

[7]Based on results of three laboratories using four natural water samples containing increments of inorganic nitrate of 0.29, 0.35, 2.31 and 2.48 mg N/l (USEPA 1979c).

[8]Based on EMSL-CIN test of surface water samples at concentrations of 15, 57, 154 and 193 mg/l as $CaCO_3$ (USEPA 1979c).

[9]Based on EMSL-CIN test of surface water samples at concentrations of 31 and 149 mg/l as $CaCO_3$ (USEPA 1979c).

TABLE 5. LABORATORY METHODS, PRECISION, ACCURACY, AND RANGE FOR SELECTED WATER QUALITY PARAMETERS

Parameter	STORET No.	Method	Precision As Std Dev. (mg/l)	Accuracy as Bias (%)		Range (mg/l)
Hardness, Total (as $CaCO_3$)	00900[1]	APHA (1980) 314A	2	2		2
Organic Carbon, Total (TOC)	00680	USEPA (1979c)[3]	3.93[3]	+15.27[3]		>1.0
Residue, Total	00500	USEPA (1979c) 160.3	±4%[4]	NA[4]		10-20,000
Residue, Nonfilterable (Suspended)	00530	USEPA (1979c) 160.2	±5.2[5] ±24	NA[5]		4-20,000
Residue, Filterable	703300	(6)	±13			
Cyanide, Total (CN)	00720	USEPA (1979c) 335.2	±0.005[7] ±0.007 ±0.031 ±0.094	85% recovery[8] 102% recovery		0.02-1.0
Chlorine, Total Dissolved	50060	Hach[9] Kit	0.385[10] 1.032 1.450	±54.0[11] ±41.9 ±16.0	±82.46[12] ±8.06 ±18.37	0-0.5 0.6-1.2 1.2-1.5

[1]STORET No. refers to USEPA methods 130.1 and 130.2.
[2]Dependent upon limitations of calcium and magnesium analyses (see Table 5).
[3]Based on results from twenty-one laboratories using distilled water containing increments of oxidizable organic compounds of 4.9 and 107 mg/l TOC.
[4]Precision estimate from APHA (1980). Accuracy data are not available (USEPA 1979c).
[5]Precision varies with concentration; values based on analyses of samples containing 15, 242 and 1,707 mg/l; accuracy cannot be determined (APHA 1980).
[6]Determined by subtracting nonfilterable residue from total residue.
[7]Based on EMSL-CIN test using mixed industrial and domestic waste samples at concentrations of 0.06, 0.13, 0.28 and 0.62 mg/l CN (USEPA 1979c).
[8]Based on EMSL-CIN test using mixed industrial and domestic waste samples at concentrations of 0.28 and 0.62 mg/l CN (USEPA 1979c).
[9]Personal communication Larry B. Lobring, EMSL-CIN June 23, 1982.
[10]Based on analyses of 16 samples with four replicates per sample.
[11]Percent positive bias based on analyses of same samples using Amperometric method.
[12]Percent positive bias based on analyses of same samples using Colorometric method.

TABLE 6. PRECISION, ACCURACY, AND DETECTION LIMITS[1] FOR SELECTED METALS IN WATER USING INDUCTIVELY COUPLED PLASMA EMISSION SPECTROMETRIC METHOD (ICP)

		Precision and Accuracy[2,3]					
Parameter	STORET No.	True Value (µg/l)	Mean Value (µg/l)	$\overline{x}$ % RSD	Wavelength[2,3] (nm)	Detection[2,3] Limit (µg/l)	Detection[4] Limit (µg/l)
Aluminum		700	696	5.6	308.2	45	230
Total	01105	60	62	33			
Dissolved	01106	160	161	13			
Arsenic		200	208	7.5	193.7	53	110
Total	01002	22	19	23			
Dissolved	01000	60	63	17			
Cadmium					226.5	4	7.5
Total	01027						
Dissolved	01025						
Calcium					317.9	10	
Total	00916						
Dissolved	00915						
Chromium		150	149	3.8	267.7	7	5
Total	01034	10	10	18			
Dissolved	01030	50	50	3.3			
Copper		250	235	5.1	324.7	6	11
Total	01042	11	11	40			
Dissolved	01040	70	67	7.9			
Lead		250	236	16	220.3	42	120
Total	01051	24	30	32			
Dissolved	01049	80	80	14			
Magnesium					279.1	30	
Total	00927						
Dissolved	00925						
Nickel		250	245	5.8	231.6	15	9
Total	01067	30	28	11			
Dissolved	01065	60	55	14			
Selenium		40	32	21.9	196.0	75	200
Total	01147	6	8.5	42			
Dissolved	01145	10	8.5	8.3			
Silver					328.0	7	12
Total	01077						
Dissolved	01075						
Zinc		200	201	5.6	213.8	2	9
Total	01092	16	19	45			
Dissolved	01090	80	82	9.4			

[1]Detection limits are sample dependent and may vary as the sample matrix varies.

[2]USEPA (1979a).

[3]Martin, J. D. and J. F. Kopp. (No date)

[4]Personal Conversation, G. V. Alexander, UCLA, 1980.

Laboratory Analysis --

It has long been known that different particle sizes have different affinities for metals and other positive ions (Namminga and Wilhm 1977; McDuffie et al. 1976); and that the most important particle sizes known to sorb positive ions range from fine sand down to clay. For this reason preliminary tests were conducted in the laboratory prior to final sediment analyses to determine the particle size range sorbing the most metals and expressing least among-replicate variability. Whole samples and 100, 250, and 400 mesh sieved subsamples from Prickly Pear Creek, Montana, sediments were previously analyzed for total recoverable metal (U.S. EPA 1981; Miller et al. 1982). Based on this experiment, 400 mesh (64 μm) particle sizes were found to contain the most metal per gram sample and to exhibit the least between-replicate variation.

Replicate core samples from Silver Bow Creek and Clark Fork were shipped to EMSL-LV, oven-dried at 100°C to complete dryness, and sieved through a 400 mesh (64 μm) stainless steel sieve. Each sample was then divided into four equal portions. Two 1-gram subsamples were then acid extracted. An extraction medium of 5 mls of HCl and 0.5 mls H_2SO_4 in 50 mls of water was found to be the most effective extraction solvent (U.S. EPA 1981). These solution subsamples were then placed in 20 dram scintillation vials and sent to UCLA for ICP analyses (Alexander and McAnulty 1981).

BIOLOGICAL

Table 7 summarizes the biological parameters measured, collection techniques, and analytical methods. A more detailed description of methods used to sample and analyze each parameter is presented below.

Macroinvertebrates

Field Collection --

Several sampler types were used in the Silver Bow/Clark Fork study to collect macroinvertebrates because substrate conditions varied at different stations. The Standardized Traveling Kick Method (STKM) (Pollard and Kinney 1979) was used to collect invertebrate samples at stations 026, 021, 023, and 025. Three replicates were collected at each site using a 30-mesh triangular dip net with a mouth opening of 25 cm x 25 cm x 25 cm and a length of 76 cm. Kick samples were standardized by the investigator holding a net in the water in front of him for 30 seconds while traveling approximately four meters downstream vigorously kicking the substrate. This sampled an area approximately 0.75 x 4 meters (3 m^2). Five replicate Portable Invertebrate Box Samples (PIBS) (Ellis-Rutter Associates 1973) were collected at station 024 in Silver Bow Creek, where the large boulder substrate made kick sampling ineffective. Three replicate Ekman grab samples were taken in the Anaconda Fish and Wildlife Sedimentation Ponds (station 027) where the substrate was silt and mud.

After collection, samples were washed through a 30-mesh sieve-bottom bucket, placed in a white enamel pan, and field-sorted to major taxonomic groups. Field extraction efficiency of each sample was checked by another field team member as a quality control measure. This quality assurance check involved scanning the sorting pan until no additional macroinvertebrates were

TABLE 7. SUMMARY OF BIOLOGICAL PARAMETERS SAMPLED IN SILVER BOW CREEK AND CLARK FORK, MONTANA, AND ASSOCIATED METHODS

Tissue Concentrations of Toxic Metals	Ecological Indicators
Aquatic Macrophytes (Representative species at each station, analyzed by DC arc spectroscopy)	Periphyton (Unit area periphyton scrape from natural rock substrate)
Root tissue Leaves and stems	Species identification Relative abundance counts
Fish (Electrofishing; analyzed by DC arc spectroscopy)	Invertebrates (Standardized Traveling Kick Method; Portable Invertebrate Box Sampler; Ekman grab)
Gill Muscle Liver Kidney Gonad* Brain* Eye* Whole body**	Species identification Relative abundance counts Fish (Electrofishing) Species identification Relative abundance Length/weight relationships

* Selected individuals from locations with extremely high metal concentrations.

** Whole fish were analyzed in small specimens.

observed for two minutes of continuous scanning. Sorted invertebrates and any unsorted samples were preserved in the field with approximately 10 percent formalin and returned to UNLV for final processing.

Laboratory Analysis --

Collected benthic invertebrates were identified to the lowest possible taxonomic level and counted at UNLV. Laboratory quality assurance sorting criteria were the same as for field sorting when additional sorting was required. Some members of the order Diptera were only identified to the subfamily level (e.g., Chironominae); members of the Oligochaeta were keyed only to class. A reference collection of identified specimens is stored at the UNLV laboratory, and samples were submitted to the University of Idaho for taxonomic verifications by C. E. Hornig.

Macroinvertebrate data were compiled and stored in a local PDP 1170 computer system. Invertebrate data analyses for Silver Bow Creek and Clark Fork consisted of: 1) total number of individuals (standing crop), 2) total number of taxa (species richness), and 3) relative species abundance.

Plants

Periphyton --

Field Collection--Periphyton was collected from riffle zone rock substrates. Replicate rocks from each station were selected in areas of uniform flow and velocity within the riffle. Algae growing onto or attached to rocks (epilithic) were sampled within a circular area of 3772 mm^2, the boundaries delimited by a flexible rubber ring. The rubber ring was placed on top of rocks which had been removed from the river and placed into shallow enamel pans. The area within the ring boundary was scraped with a razor blade and stiff nylon brush into a 500 ml glass jar. This procedure was repeated for each replicate sample at each station. Each replicate volume was then adjusted to a standard volume by adding distilled water. Lugol's preservative was added to each sample to produce a final concentration of 1 to 5 percent depending upon algal biomass present.

Laboratory Analysis--Periphyton counting and identification included two analytical steps: 1) one subsample was acid-cleaned to identify diatom species and to obtain proportional counts, and 2) a second subsample was examined with an inverted microscope to count and identify nondiatoms and to obtain a total count of all viable diatom frustules to convert proportional diatom counts to cells/mm^2.

A. Diatom Proportional Count

One 10 to 20 ml subsample was removed with a wide-bore pipette and placed into a 25 ml Erlenmeyer flask; five ml of concentrated nitric acid (HNO_3) were then added. Flasks were placed on a heating plate inside a fume hood and samples were mildly boiled for approximately 5 minutes or until sample color became clear. This procedure oxidized sample organic material and broke up gelatinous material, leaving the siliceous diatom frustules intact. Each subsample was then centrifuged for 5 minutes. The supernatant was decanted and the centrifuge tube refilled with distilled water. This procedure was repeated

two additional times to remove any remaining HNO_3. After final centrifugation, one or two drops of concentrated sample were placed on a cover glass and mounted with Hyrax™ mounting media. The edge of the slide was sealed with clear fingernail polish.

Diatoms were identified and counted at 1000x magnification (oil immersion) with an Olympus BHT phase contrast microscope. Long counts of 5000-10000 diatoms or more, such as are recommended by Patrick (1977), are too time consuming for most water quality studies; hence, we scanned random strips until at least 300 diatom cells were counted and identified (Weitzel 1979). Counting fewer diatoms (300) provides reliable results (Weber 1973) and compares well with longer counts of 1000 diatoms (Castenholtz 1960).

B. Non-Diatom Count

A 0.05 to 2.0 ml subsample was introduced into a Wild™ plate chamber. Strips were scanned across the entire counting chamber diameter under 100-400X magnification using an Olympus IMT inverted microscope. All nondiatoms were counted and identified during this step as well as total viable diatom frustule number. If excess clumping was evident, the sample was placed in a "sonifier" unit to break up clumps and filaments.

Calculations

(1) Counting accuracy = $2 \cdot \frac{100}{\sqrt{n}}$ (Lund et al. 1958)

(2) Cell abundance (cells mm^{-2}) = $\frac{(A_c)\ (V_s)\ (X_i, X_D)}{(L_s)\ (W_s)\ (N_s)\ (V_a)\ (A_s)}$

where

A_c	=	area of counting plate chamber (510 mm^2)
V_s	=	volume of sample (ml)
X_i	=	counts of nondiatom species
X_D	=	total count of viable diatom frustules
L_s	=	length of strip(s) counted (25 mm)
W_s	=	width of strip(s) counted (mm)
N_s	=	number of strip(s) counted (1,2,3,4)
V_a	=	volume of subsample (0.05-2.0 ml)
A_s	=	area of rock scraped as delineated by rubber ring (3772 mm^2)
n	=	number of diatom frustules counted

Total diatom abundance was converted to relative abundance of each species by [formula 2] x $\frac{N_i}{N_D}$

where

N_i = number of occurrences of each species in the proportional count
N_D = total number of diatom frustules counted in the proportional count

Macrophyte Tissues--

Field Collection--Macrophytes from the family Juncaceae (rushes) were collected for tissue analysis from banks where the root zone was in contact with stream water. Random samples of whole plants (leaves, stems, and roots) were collected in triplicate from each station. These samples were frozen and shipped to EMSL-LV on dry ice.

Laboratory Analysis--Macrophyte samples were thawed, roots and stems were separated at the soil surface level, and each part washed three times in distilled water. Each washing consisted of placing the sample in a 16 oz Nalgene bottle, filling to 1/3 volume, and agitating for one minute. All plant samples were oven dried at 80°C to complete dryness, placed in plastic 20 dram vials, and homogenized with a Model 8000 Mixer Mill (Spex Industries Inc.). Approximately 1 gm samples were then placed in 20 dram scintillation vials and sent to UCLA for analysis by DC Arc Spectrometry (Alexander and McAnulty 1981).

Fish

Community Census --

Fish samples taken in this study were qualitative collections with emphasis placed on presence or absence of various fish species upstream and downstream from the primary discharge. Sampling was conducted by electrofishing with a backpack shocker. All fish were identified, weighed, and measured in the field.

Tissues--

Field Collection--Mature fish from a variety of families were collected from each station where available; each was frozen, and shipped on dry ice to EMSL-LV. The fish were later thawed and liver, gill, muscle, and kidney tissues dissected from each fish. Brain, gonad, and eye tissues were also extracted to compare metal accumulation in various tissues.

Laboratory Analysis--Triplicate samples of approximately 1 gm from each tissue type were freeze dried and sent to UCLA's Laboratory of Biomedical and Environmental Science for DC Arc Spectrometry analysis (Alexander and McAnulty 1981). At UCLA each of 3 subsamples was individually weighed and analyzed for metal content.

Bioassays--

Field Collection--Water samples from stations 021 and 023 were collected in 5 gallon cubitainers, packed in ice, and shipped to ERL-Duluth and ERL-Corvallis for bioassay.

Laboratory Analysis--At Corvallis, bioassays using *Daphnia* and steelhead trout (*Salmo gairdneri*) were conducted on whole water samples. Algal assay tests with *Selenastrum capricornutum* were also performed using serial dilutions to test inhibition of growth response. The Duluth work consisted of experiments on: 1) an activity index of bluegill sunfish (*Lepomis macrochirus*); 2) 48-hr acute toxicity to *Daphnia magna*; 3) immobilized enzymes; and 4) chlorophyll *a* fluorescence using *Selanastrum capricornutum*. Additional information on these latter two experimental tests can be obtained from ERL-Duluth.

III. RESULTS AND DISCUSSION

CHEMICAL

Water Quality

Several publications have identified water quality parameters which may alter metal toxicity in controlled laboratory bioassays (Lloyd and Herbert 1962; Nishikawa and Tabata 1969; Brown et al. 1974; Shaw and Brown 1974; Howarth and Sprague 1978; Waiwood and Beamish 1978; Miller and Mackay 1980). These parameters include hardness, alkalinity, pH, temperature, and turbidity from dissolved or particulate matter. An attempt was made to accurately characterize water quality in Silver Bow Creek and Clark Fork by identifying and quantifying as many parameters as feasible (Appendix A). Metal data both from mid-depth grab samples and ISCO 24-hour automatic collections (to provide information on diel changes) are included in Appendix A.

Water samples were analyzed for total and dissolved metal concentrations and compared with U.S. EPA (1980) recommended acute criteria for aquatic life based upon water hardness (Table 8). Total arsenic, cadmium, chromium, copper, selenium, and zinc concentrations all exceeded recommended criteria at one or more Silver Bow or Clark Fork stations. This is consistent with data reported by Peckham (1979) and WESTECH (1979) showing copper and zinc concentrations in Silver Bow Creek to be at levels potentially toxic to fish. Much of these metals (84% of the copper increases between Butte and Gregson Hot Springs, and 46% of the zinc) are from nonpoint sources (Peckham 1979), particularly the inflow of metal-rich ground water from the Colorado Tailings Pile near Butte. Peckham (1979) concludes, "The results of this study indicate it may not be feasible to reduce metals concentrations in Silver Bow Creek to levels tolerable to aquatic life".

Analyses of variance (ANOVA) and Bartlett's test for homogeneity of variances were performed to test for significant differences among stations for eight ambient total metals in Silver Bow Creek and Clark Fork (Table 9). With chromium, copper, and zinc, ANOVA parametric assumptions for normality and heterogeneity of variances were not met, so a Kruskal-Wallis ANOVA by ranks (Siegel 1956) was used to test for significant differences. When ANOVA F-ratios indicated significant differences ($p = 0.05$) in metal concentrations, the Student-Newman-Keuls (SNK) stepwise multiple range test was calculated (Sokal and Rohlf 1981) to determine among which of the six stations differences occurred (Table 10).

TABLE 8. COMPARISON OF MEAN TOTAL CONCENTRATIONS OF SELECTED METALS VERSUS CALCULATED ACUTE WATER QUALITY CRITERIA FOR AQUATIC LIFE IN SILVER BOW CREEK AND CLARK FORK, MONTANA. Means represent three or more analytical replicates (mid-depth grabs and ISCO samples combined) unless otherwise indicated; ISCO samples were not available from Stations 027 and 023.

	Station					
	Upstream (impact) Silver Bow Creek			Pond	Downstream Clark Fork River	
	026	024	021	027	023	025
Hardness (mg/l)	648	517	444	540	445	422
Total metals (µg/l)						
Arsenic (Detection Limit = 110.0)						
actual ($\bar{X}$)	160.0*	619.2	878.0	2577.5	961.0	258.0
criterion	440	440	440	440	440	440
Cadmium (Detection Limit = 7.5)						
actual ($\bar{X}$)	29.0	19.8	19.0	15.2	ND	15.5
criterion	21	17	14	18	14	14
Chromium (Detection Limit = 5.0)						
actual ($\bar{X}$)	32.6	17.6	18.5	29.6	27.1	30.0
criterion*	21	21	21	21	21	21
Copper (Detection Limit = 11.0)						
actual ($\bar{X}$)	345.8	372.2	342.8	34.0	30.2	28.7
criterion	128	104	90	108	90	86
Lead (Detection Limit = 120.0)						
actual ($\bar{X}$)	302.7	184.5	120.0	270.2	123.6	217.9
criterion	1681	1277	1060	1347	1065	997
Nickel (Detection Limit = 9.0)						
actual ($\bar{X}$)	12.0**	56.2	68.2	181.5	62.3	24.5
criterion	7629	6426	5724	6645	5740	5508
Selenium (Detection Limit = 200.0)						
actual ($\bar{X}$)	ND	ND	ND	304.0	ND	ND
criterion	260	260	260	260	260	260
Silver (Detection Limit = 12.0)						
actual ($\bar{X}$)	50.1	22.2	23.4	43.6	27.6	25.8
criterion	101	68	53	74	53	48
Zinc (Detection Limit = 9.0)						
actual ($\bar{X}$)	1741.2	840.5	712.5	305.8	112.3	106.4
criterion	1514	1256	1107	1302	1110	1061

* Criteria are for hexavalent chromium. Hardness dependent criteria for trivalent chromium are not presented because Cr in the trivalent state is rarely present in natural water with a pH above 5 (U.S. EPA 1976).
** One data point only.
ND=nondetectable.

TABLE 9. SIGNIFICANCE LEVELS OF BARTLETT'S TESTS, ANOVA F-RATIOS, AND KRUSKAL-WALLIS ANOVAS BY RANKS FOR TEST OF DIFFERENCES AMONG STATIONS FOR AMBIENT WATER METAL CONCENTRATIONS, SILVER BOW CREEK AND CLARK FORK, MONTANA

Total Metal	Bartlett's	ANOVA F-Ratio	Kruskal-Wallis
Arsenic	NS	NS	
Cadmium	NS	***	
Chromium	**		**
Copper	**		**
Lead	NS	***	
Nickel	NS	**	
Silver	NS	**	
Zinc	**		**

NS=Nonsignificant
 * p=0.05
** p=0.005
***p=0.001

TABLE 10. STUDENT-NEWMAN-KEULS STEPWISE MULTIPLE RANGE TEST (SNK) OF AMBIENT WATER METAL CONCENTRATIONS, SILVER BOW CREEK AND CLARK FORK, MONTANA. Nonsignificant (p=0.05) subsets of group means are indicated by horizontal lines. Means based upon triplicate mid-depth grabs unless otherwise indicated.

	Stations					
	Upstream (Impact)			Pond	Downstream	
Total Metal (μg/l)	026	024	021	027	023	025
Cadmium $\bar{X}$ SNK	23.5	11.2	ND	15.2	ND	10.2
Chromium $\bar{X}$ SNK	29.2	15.3	18.2	29.6	27.1	28.5
Copper $\bar{X}$ SNK	319.8	368.8	356.7	34.0	30.2	29.3
Lead $\bar{X}$ SNK	265.0	158.5	ND	270.2	123.6	192.2
Nickel $\bar{X}$ SNK	12.0*	67.3	63.3	181.5	62.3	25.7
Silver $\bar{X}$ SNK	47.5	17.2	23.8	43.6	27.6	20.8
Zinc $\bar{X}$ SNK	1705.0	825.2	731.3	305.8	112.3	100.8

*Single data point.
ND= nondetectable.

Results of the SNK test showed highly variable distribution patterns for all nine metals in the Silver Bow/Clark Fork drainage area, reflecting the complex nature of the metal discharges to the system (Table 10). Results of two-way nested ANOVAs using ambient metal data from triplicate mid-depth grabs show that the greatest percentage (58-99%) of variability observed in the total metal concentrations in Silver Bow Creek and Clark Fork was due to between-station differences rather than analytical or field replicate variation (Table 11). Although among-station differences also accounted for much of the variance in the dissolved metal data (25-68%), an increased proportion of the dissolved metal variability was due to field "replicate" or analytical measurement differences.

The dissolved fraction of metals has long been implicated as being the most toxic form to aquatic life. This has been demonstrated by toxicity tests (Shaw and Brown 1974; Howarth and Sprague 1978) and several treatments of metal species equilibrium models (Pagenkopf et al. 1974; Andrew et al. 1977; McCrady and Chapman 1979). These models correlate metal toxicity with the free ion concentrations as well as the presence of carbonate (CO_3^{--}) or hydroxide (OH^-) molecular forms.

Ambient total and dissolved metal concentrations were compared at all stations in Silver Bow Creek and Clark Fork (Table 12). In most cases, a sizable percentage (>50%) of total metal concentrations occurred in the dissolved fraction at all stations. Copper and zinc dissolved fractions in Silver Bow Creek were considerably lower than in downstream Clark Fork. In some cases, mean dissolved metal concentrations apparently exceeded mean total metals (Table 12). This anomaly generally occurs 1) when confidence intervals around the dissolved and total metal means overlap, indicating no statistically significant ($p = 0.05$) difference between them (e.g. silver), or 2) when metal concentrations such as cadmium and silver are near or below ICP detection limits.

In addition to elevated metals, sulfate concentrations in the Upper Clark Fork River have been reported (WESTECH 1979) in excess of Montana Water Quality Standards (250 mg/l). During 1980, sulfate concentrations in Silver Bow Creek ranged from a high mean of 664 mg/l at Gregson (Station 026), to a low of 401 mg/l at Station 021.

Sediments

Analysis of variance and Bartlett's test for homogeneity of variances were performed to test for significant differences in five metals from five stations in Silver Bow Creek and Clark Fork (Table 13). A Kruskal-Wallis ANOVA by ranks was used for the cadmium data, which did not meet ANOVA parametric assumptions for normality and heterogeneity of variances. Patterns of differences among stations were tested using SNK multiple range procedure where significant ($p = 0.01$) differences did occur. However, SNK results were highly variable (Table 14). Copper and zinc sediment concentrations were highest in the Anaconda pond (027) and lowest at the station downstream (025). Arsenic concentrations were significantly highest in the furthest upstream impact station (026); chromium concentrations were highest at Station 024.

TABLE 11. VARIANCE COMPONENTS OF MEAN TOTAL AND DISSOLVED CONCENTRATIONS OF SELECTED METALS* IN WATER SAMPLES (mid-depth grabs only), SILVER BOW CREEK AND CLARK FORK, MONTANA

Metal	Among Stations	Within Field Replicates	Within Laboratory Replicates
Cadmium			
Dissolved	66%	24%	10%
Total	85%	8%	7%
Chromium			
Dissolved	68%	20%	12%
Total	58%	33%	9%
Copper			
Dissolved	59%	41%	< 1%
Total	99%	< 1%	< 1%
Lead			
Dissolved	68%	19%	13%
Total	79%	4%	17%
Silver			
Dissolved	25%	38%	37%
Total	62%	19%	18%
Zinc			
Dissolved	56%	44%	< 1%
Total	95%	5%	< 1%

*Nested ANOVAs were only run on metal data at stations with equal sample size. Those metals having fewer than six data points at five stations are not included in this table.

TABLE 12. MEAN TOTAL AND DISSOLVED CONCENTRATIONS (µg/l) OF SELECTED METALS (mid-depth grabs only) AT EACH STATION IN SILVER BOW CREEK AND CLARK FORK, MONTANA. (Numbers enclosed in parentheses are 95% confidence intervals*.)

	Station					
	026	024	021	027	023	025
			Arsenic (Detection Limit = 110)			
Total	160 (-)**	732.6 (1474.2)	1037.0 (868.4)	2577.5 (2410.1)	961.0 (336.7)	521.0 (452.4)
Dissolved	1300 (-)**	535.0 (267.4)	787.0 (785.6)	1453.0 (1081.6)	671.3 (458.6)	454.0 (-)
% Dissolved	100	73	76	56	70	87
			Cadmium (Detection Limit = 7.5)			
Total	23.5 (3.2)	11.2 (2.2)	ND	-	ND	10.2 (2.2)
Dissolved	22.3 (4.4)	12.0 (5.2)	ND	-	ND	10.2 (3.6)
% Dissolved	95	100	-	-	-	100
			Chromium (Detection Limit = 5)			
Total	29.2 (1.9)	15.3 (2.8)	18.2 (2.3)	29.8 (9.9)	27.0 (1.9)	28.5 (3.0)
Dissolved	33.5 (5.2)	19.6 (5.2)	16.0 (2.3)	23.5 (3.9)	24.3 (1.4)	28.3 (4.2)
% Dissolved	100	100	88	79	90	99
			Copper (Detection Limit = 11)			
Total	319.8 (15.6)	368.8 (7.2)	356.6 (2.4)	-	30.2 (2.3)	29.3 (2.4)
Dissolved	72.8 (4.2)	74.0 (45.2)	63.2 (11.9)	-	20.8 (2.0)	23.2 (1.8)
% Dissolved	23	20	18	-	69	79
			Lead (Detection Limit - 120)			
Total	265.0 (27.4)	158.5 (41.1)	ND	-	123.7 (48.0)	192.2 (16.2)
Dissolved	288.8 (56.4)	201.8 (68.4)	ND	-	ND	171.2 (48.4)
% Dissolved	100	100	-	-	-	89

*Confidence intervals that overlap indicate total and dissolved mean metal concentrations are not significantly (p=0.05) different.
**One data point only. All other means are based on three or more analytical replicates.
ND=nondetectable.
- indicates no data available.

Continued

TABLE 12. (Continued)

	Station					
	026	024	021	027	023	025
			Nickel (Detection Limit = 9)			
Total*	12 (-)**	67.3 (22.4)	63.3 (7.9)	181.5 (145.2)	62.3 (31.9)	25.6 (19.9)
Dissolved	-	34.6 (23.8)	51.0 (13.1)	103.6 (97.3)	36.3 (24.8)	12.0 (15.5)
% Dissolved	-	51	81	57	58	47
			Selenium (Detection Limit = 200)			
Total	ND	ND	ND	304.0 (307.4)	ND	ND
Dissolved	-	ND	ND	ND	ND	ND
% Dissolved	-	-	-	-	-	-
			Silver (Detection Limit = 12)			
Total	47.5 (10.0)	17.2 (9.3)	23.8 (6.2)	-	27.6 (8.3)	20.8 (5.7)
Dissolved	45.0 (18.6)	25.5 (9.6)	23.8 (4.0)	-	26.8 (8.2)	26.6 (7.3)
% Dissolved	95	100	100	-	97	100
			Zinc (Detection Limit = 9)			
Total	1705.0 (45.8)	825.6 (10.6)	731.3 (4.8)	-	112.3 (2.0)	100.8 (3.9)
Dissolved	558.2 (164.3)	202.0 (179.8)	208.6 (232.8)	-	86.8 (8.6)	91.2 (6.4)
% Dissolved	33	24	28	-	77	90

**One data point only. All other means are based on three or more analytical replicates.
ND=nondetectable.
- indicates no data available.

TABLE 13. SIGNIFICANCE LEVELS OF BARTLETT'S TESTS, ANOVA F-RATIOS, AND KRUSKAL-WALLIS ANOVAS BY RANKS FOR TEST OF DIFFERENCE AMONG STATIONS FOR METAL CONCENTRATIONS IN SEDIMENTS, SILVER BOW CREEK AND CLARK FORK, MONTANA

Metal	Bartlett's	ANOVA F-Ratio	Kruskal-Wallis
Arsenic	NS	***	
Cadmium	***		*
Chromium	NS	**	
Copper	NS	***	
Zinc	NS	***	

* ρ=0.05
** ρ=0.01
*** ρ=0.005
NS = nonsignificant

TABLE 14. STUDENT-NEWMAN-KEULS STEPWISE MULTIPLE RANGE TEST OF METAL CONCENTRATIONS IN SEDIMENTS, SILVER BOW CREEK AND CLARK FORK, MONTANA. Nonsignificant (p=0.05) subsets of group means are indicated by horizontal lines. Means based on 4 or 6 replicates.

	Stations				
	Upstream (Impact)			Pond	Downstream
Total Metal (mg/kg)	026	024	021	027	025
Arsenic					
$\overline{X}$	337.2	ND	159.7	155.7	ND
SNK					
Chromium					
$\overline{X}$	26.4	45.2	13.3	30.8	11.2
SNK					
Copper					
$\overline{X}$	3852.8	880.2	2481.9	6152.9	282.4
SNK					
Zinc					
$\overline{X}$	3827.8	425.3	2334.8	7653.6	363.4
SNK					

ND=nondetectable.

BIOLOGICAL

Macroinvertebrates

There were 43 distinct macroinvertebrate taxa identified in Silver Bow Creek and Clark Fork during the August 1980 sampling effort (Table 15). Benthic populations were compared at all stations (Appendix B) throughout the river to assess the impact of elevated metal concentrations on biological communities. It should be noted that not all taxonomic groups were identified to species level. Although analyses in the following discussion do not report the exact number of taxa and diversities at each site, they are of value for comparative purposes.

Upstream Impact Stations (026 and 021)--

Because of the different sampler types used to collect macroinvertebrates in Silver Bow Creek and Clark Fork, only stations 026 and 021 were numerically compared in Silver Bow Creek (Table 15). Station 026 contained 14 taxa, but total counts were 92% comprised of orthoclad midges (Figure 3). Three taxa (Rhyacophila sp., Doroneuria sp., and Culex sp.) were collected only at this site; conversely, two taxa (Hydropsyche sp., Liodessus/Oreodytes complex) were collected at every comparison site except this one. Station 021 contained 12 taxa, with 75% relative abundance of orthoclad midges. Two taxa (Dicranota sp., Psychoda sp.) were collected only at this site. The mite, Sperchon sp., was collected at both stations, but was not found downstream in Clark Fork. These results are striking if compared with Peckham (1979), who reported on a 1973-75 study by the Anaconda Company in Silver Bow Creek. He states, "Although the predominant species of organisms [midges, craneflies, near Gregson] suggested that environmental stresses still existed in the aquatic habitat, the presence of any life was encouraging."

Downstream Recovery Stations (025 and 023)--

There were 26 taxa collected at station 023 in Clark Fork downstream from the Anaconda Fish and Wildlife Sedimentation Ponds. Orthoclad and Tanypodinae midges were common (Table 15), as was the caddisfly, Hydropsyche sp. There were 27 taxa collected at station 025, with Baetis sp. making up 48% of the total counts. Hydropsyche sp., orthoclad midges, and black flies were also common. The water mite, Lebertia sp., apparently replaced Sperchon in these downstream Clark Fork stations. Eight different caddisfly (Trichoptera) genera, representing seven families, and three crane fly genera (Hexatoma, Tipula, and Antocha) that had not been found in the upstream Silver Bow impacted sites were collected in Clark Fork. These data indicate that the Anaconda ponds are acting as an effective "sink" for suspended solids and associated metals, allowing considerable diversification to occur in the macroinvertebrate community.

One-way ANOVA and Bartlett's tests for homogeneity of variances were performed to test for significant differences between these four stations in relative abundances, species richness, and Shannon-Wiener diversity (Southwood 1978). Total counts and number of taxa showed statistically nonsignificant ($p = 0.05$) results. The ANOVA F-ratio did demonstrate significant ($p = 0.05$) differences among stations using diversity, so an SNK multiple range test was calculated. Results of the SNK test showed diversities from the Silver Bow

TABLE 15. DISTRIBUTION AND RELATIVE ABUNDANCE (collected in 30-second kicks) OF MACROINVERTEBRATE TAXA, AUGUST 1980, SILVER BOW CREEK AND CLARK FORK, MONTANA [A=Abundant (61-100%), VC=Very Common (31-60%), C=Common (6-30%), O=Occasional (1-5%), R=Rare (<1%)]

	Stations			
	Upstream		Downstream	
Taxa	026	021	023	025
Ephemeroptera				
Baetidae				
Baetis spp.	R		R	VC
Baetis bicaudatus			R	
Plecoptera				
Perlidae				
Doroneuria sp.	R			
Perlodidae				
Isoperla sp.	R		O	O
Pteronarcidae				
Pteronarcella badia			O	R
Megaloptera				
Sialidae				
Sialis sp.			R	
Trichoptera				
Hydropsychidae				
Hydropsyche sp.		R	C	C
Cheumatopsyche sp.			O	R
Leptoceridae				
Mystacides sp.*				
Oecetis prob. *avara*			O	R
Brachycentridae				
Brachycentrus sp.				R
Hydroptilidae				
Hydroptila sp.				R
Stactobiella sp.			O	
Helicopsychidae				
Helicopsyche borealis			O	R
Rhyacophilidae				
Rhyacophila sp.	R			
Glossosomatidae				
Agapetus sp.			O	
Limnephilidae				
Onocosmoecus sp.				R

Continued

*Collected only in sedimentation ponds (027) or at station 024 (Silver Bow). Because of differences in sampler type (site 024-PIBS box sampler; 027-Ekman grab) relative abundances are not comparable.

TABLE 15. (Continued)

Taxa	Stations: Upstream 026	021	Downstream 023	025
Diptera				
Chironomidae				
Tanypodinae			C	O
Chironominae	R			R
Tanytarsini*				
Orthocladiinae	A	A	C	C
Corynoneura/Thienemanniella complex				
Simuliidae		R	O	O
Simuliium sp.				C
Culicidae				
Culex sp.	R			
Empididae	R		R	R
Tipulidae				
Hexatoma sp.			O	O
Tipula sp.			R	R
Antocha sp.				R
Dicranota sp.		R		
Rhagionidae				
Atherix variegata	R		O	R
Psychodidae				
Psychoda sp.		R		
Coleoptera				
Elmidae				
Zaitzevia parvula			R	R
Optioservus quadrimaculatus	R	O	O	O
Narpus concolor				R
Cleptelmis addenda		R		R
Dytiscidae				
Oreodytes sp.	R	O	O	R
Liodessus/Oreodytes complex		R	O	R
Agabus sp.	R	O		
Haliplidae				
Brychius hornii	R		O	
Hydracarina				
Lebertiidae				
Lebertia sp.			R	R
Sperchonidae				
Sperchon sp.	R	R		
Amphipoda				
Hyalella azteca			R	
Oligochaeta		R	R	
Hirudinea*				

*Collected only in sedimentation ponds (027) or at station 024 (Silver Bow). Because of differences in sampler type (site 024-PIBS box sampler; 027-Ekman grab) relative abundances are not comparable.

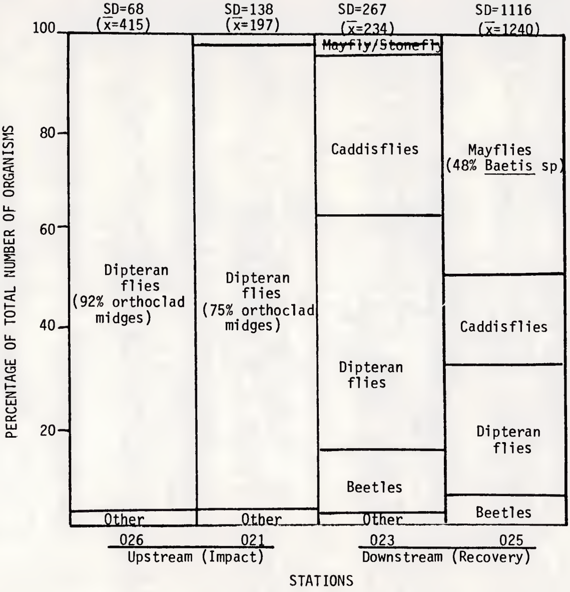


Figure 3. Percentage composition of major macroinvertebrate groups at stations in Silver Bow Creek and Clark Fork, Montana. (Numbers at the top of each station indicate mean total counts ($\overline{x}$) and standard deviations (SD) per replicate sample, n=3.)

stations were significantly ($p = 0.05$) lower (station 026 = 0.5217, station 021 = 0.9880) than those in Clark Fork (station 023 = 2.9070, station 025 = 2.2577).

Changes in benthic species composition were compared to mean concentrations of trace metals in Silver Bow Creek and Clark Fork. The literature describes a number of environmental factors which influence trace metal toxicity to aquatic organisms (Tabata 1969; Karbe et al. 1975; LaBounty et al. 1975; Luoma and Bryan 1978). Included among those factors are: the concentration, valence, and form in which metals exist in the water column; exposure duration of the animal; stream discharge and flow velocity; chemical characteristics of the water, especially hardness, pH, and dissolved oxygen; and the nature, condition and life stage of the organism. Some organisms are especially sensitive to elevated concentrations of metals, for example, oligochaetes, leeches, crustaceans, and mollusks (Brinkhurst 1965; Hynes 1965; LaBounty et al. 1975), while others are more tolerant, although relative toxicity of metals to aquatic insects varies widely with differing taxa (Warnick and Bell 1969; Phillips and Russo 1978).

In Silver Bow Creek and Clark Fork, total arsenic, cadmium, chromium, copper, selenium, and zinc exceeded U.S. EPA recommended acute water quality criteria in the impact zone at one or more stations (Table 8). Total number of taxa, relative abundance, and species diversity were also compared to arsenic (Spearman-Rank correlations) and copper concentrations in the study area (Figure 4); however, because of the small sample size, a statistically significant correlation could not be determined.

Plants

Periphyton--

The periphyton community is important to the biological structure of a stream and the diatom component has been isolated as one of the better monitors of water quality and stream conditions (Weitzel 1979). Diatoms are useful indicators of water quality for the following reasons:

1. With their secure means of attachment to substrates, diatoms may be less subject to drift than invertebrates and are good indicators of conditions at collection locations.

2. A short generation time allows diatoms to better reflect conditions immediately prior to sampling, instead of integrating long-term effects.

3. Diatom mounts may be stored for many years, permitting re-examination at any later time.

4. Diatoms are ubiquitous on stream bottoms.

5. They are easy to collect in sufficient quantity to meet statistical requirements.

6. Diatoms have a wide and well documented range of environmental requirements and pollution tolerances.

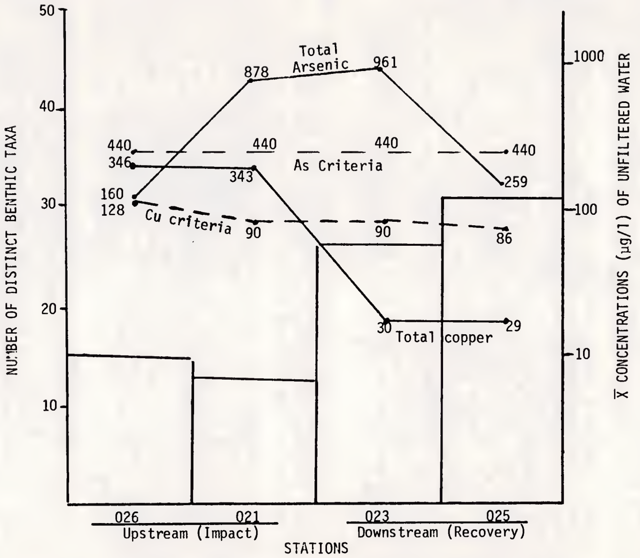


Figure 4. Comparison of benthic species richness in Silver Bow Creek and Clark Fork, Montana, mean concentrations of total copper and arsenic, and calculated copper and arsenic water quality acute criteria.

The algal community in healthy streams usually contains high numbers of species, each with relatively small populations. Stream perturbations including heavy metal pollution may alter community composition. Change may be expressed in several ways: species richness or diversity, numbers of individuals, or kinds of species (Patrick 1977). Heavy metals usually reduce species diversity and increase total algal abundance, with a few periphyton species becoming extremely common (Miller et al. 1982). However, these types of shifts are dependent upon the effects of the various kinds of pollution (Patrick 1977).

Algae present in a stream containing high heavy metal concentrations can be expected to be members of metal-resistant species or to be metal tolerant races evolved from normally sensitive species (Foster 1982). The relationship between metal pollution and species indicative of metaliferous environments (Williams and Mount 1965; Besch et al. 1972; Palmer 1977) failed to meet widespread applicability (Whitton 1970). Studies of freshwater algal resistance both in the laboratory and field have been few (Whitton and Say 1975) and results of these studies have not been consistent. For example, a laboratory study of <u>Nitzschia palea</u> (Steemann-Nielsen and Wium-Anderson 1970) indicated this diatom is very sensitive to soluble copper in the absence of any chelating agent. However, Palmer (1977) included it in a list of tolerant species 'indicative' of copper pollution. In streams affected by heavy metals, many other environmental factors may also influence the algal community; heavy metals could be considered to restrict species distributions but not define them (Foster 1982).

There were seventy-four periphyton taxa identified from Silver Bow Creek and Clark Fork, Montana, during August 1980 collections (Appendix C). Fifty-two diatom taxa (Bacillariophyceae) were identified (Table 16). The environmental requirements of some important taxa are presented in Table 17.

Green (Chlorophyta) and blue-green (Cyanophyta) species were less common, contributing sixteen and three taxa, respectively (Table 18). Cryptophyta and Euglenophyta were also observed in low abundance with few taxa represented. This assemblage reveals only a single seasonal aspect of the community and may not reflect the changes in composition and abundance due to varying light, temperature, nutrients, and flow conditions (Blum 1957; Hynes 1970). However, Foster (1982) during a year-long study reported that dominant species were stable at all sites in rivers polluted by heavy metals. This floristic stability may be due to the high selected force exerted by toxic metals and thus unadapted species would be excluded from those environments (Foster 1982).

Tables 16 and 18 list those species identified at each station and relative percent contribution in five abundance classes. These classes are based on numerical abundance (cells/mm^2), therefore, size differences between species are not reflected with these data. Each taxon receives equal numerical representation regardless of cell or frustule size. In this analysis, diatoms are treated separately and numerical comparisons between different algal divisions are avoided.

<u>Impact Zone Stations (026, 024 and 021)</u>--<u>Navicula arvensis</u> was the dominant diatom species, contributing greater than 90% relative cell abundance to the total diatom community at each station within this zone (Table 19). Mean

TABLE 16. DIATOM TAXA AND RELATIVE NUMERICAL ABUNDANCE IN SILVER BOW CREEK AND CLARK FORK, MONTANA. [A=Abundant (61-100%), VC=Very Common (31-60%), C=Common (6-30%), O=Occasional (1-5%), and R=Rare (<1%)]

	Stations				
	Impact			Recovery	
	026	024	021	023	025
Bacillariophyceae					
Centrales					
Melosira varians	R	R	R		
Cyclotella meneghiniana	R	R	R	R	R
Fragilariaceae					
Diatoma hiemale var. *mesodon*			R		
Meridion circulare		R	R		
Meridion circulare var. *constrictum*	R				
Diatoma vulgaris		R			
Fragilaria vaucheriae				O	C
Fragilaria pinnata		R	R		
Fragilaria leptostauron	R		R	R	R
Fragilaria capucina var. *mesolepta*					R
Fragilaria crotonensis var. *oregona*				R	O
Fragilaria leptostauron var. *dubia*				R	R
Fragilaria vaucheriae var. *capitellata*					R
Synedra rumpens		R	R	O	R
Synedra ulna var. *oxyrhynchus* f. *mediocontracta*		R		O	R
Synedra rumpens var. *familiaris*			R		
Synedra acus			R	R	
Synedra ulna var. *amphirhynchus*					
Hannaea arcus	R		R	R	R
Hannaea arcus var. *amphioxys*				R	
Achnanthaceae					
Achnanthes lanceolata	R		R	R	R
Achnanthes lanceolata var. *dubia*	R		R		
Achnanthes linearis					O
Achnanthes minutissima	O	O	O	C	VC
Cocconeis placentula var. *euglypta*		R	R		
Cocconeis placentula var. *lineata*	R		R	O	R
Rhoicosphaenia curvata			R		

Continued

TABLE 16. (Continued)

	Stations				
	Impact			Recovery	
	026	024	021	023	025
Naviculaceae					
Navicula arvensis	A	A	A	0	0
Navicula salinarum var. *intermedia*					R
Navicula pupula				R	R
Navicula viridula			R		R
Navicula capitata				R	
Navicula decussis			R		
Navicula tuscula		R			
Pinnularia borealis		R			
Gomphonemaceae					
Gomphonema parvulum	R		R	R	C
Gomphonema olivaceoides				R	
Cymbellaceae					
Amphora perpusilla				R	
Cymbella minuta				R	
Cymbella minuta var. *silesiaca*	R		R	0	0
Cymbella sinuata		R		R	R
Cymbella cistula				R	
Epithemiaceae					
Epithemia sorex		R			
Rhopalodia gibba	R				
Nitzschiaceae					
Nitzschia acicularis		R	R	R	
Nitzschia dissipata		R	R	R	R
Nitzschia frustulum var. *perpusilla*	R			R	R
Nitzschia hantzschiana			R		
Nitzschia palea	R	R	R	A	C
Nitzschia linearis			R	R	R
Surirellaceae					
Cymatopleura solea				R	
Surirella angustata	0	R	R	R	R
Surirella ovata	0	R	R	R	0

TABLE 17. REPORTED ENVIRONMENTAL REQUIREMENTS, INCLUDING pH RANGE AND HEAVY METAL TOLERANCE, OF ABUNDANT PERIPHYTON TAXA OBSERVED IN SILVER BOW CREEK AND CLARK FORK, MONTANA

Taxa	Distribution and Environmental Requirements
Achnanthes minutissima (Kütz)	Cosmopolitan; one of the most ubiquitous diatoms known; indicator of high dissolved oxygen concentrations; calcium and iron indifferent (Lowe 1974). Generally characteristic of unpolluted rivers (Lange-Bertalot 1979 and Besch et al. 1972). pH requirements: range 7-8 (Maillard 1959) optimum 7.5-7.8 (Cholnoky 1968) Heavy metal tolerance: low resistant: tolerant to 0.1-0.2 mg/l zinc (Besch et al. 1972).
Fragilaria vaucheriae (Kütz) Peters	Cosmopolitan; optimum pH 6.5-9.0; eurytrophic; 0-15°C (Lowe 1974). Exists with high reproductive rates in "*alpha-mesosaprobic" but not in "*polysaprobic" waters (Lange-Bertalot 1979).
Gomphonema parvulum (Kütz)	Cosmopolitan; a facilitative nitrogen heterotroph; calcium and iron indifferent (Lowe 1974); eurytrophic species (Symoens 1957); attains high abundances in running waters below effluents of organic wastes (Backhaus 1968); characteristic of excessively polluted "polysaprobic" water (Lange-Bertalot 1979). pH requirements: range 4.2-9.0 (Lowe 1974); optimum 7.8-8.2 Heavy metal tolerance: resistant to 1.5 mg/l copper (Schroeder 1939). Abundant at 0.5 mg/l chromium below chromate effluent (Breeze 1973).
Navicula arvensis Hust.	Optimum pH > 6.5; oligotrophic; warm water (Schoeman 1973).

*alpha-mesosaprobic; BOD less than 13 mg/l oxygen, and less than 75 percent oxygen deficit.
polysaprobic; BOD greater than 22 mg/l oxygen, and oxygen deficit greater than 90 percent.

TABLE 18. ATTACHED ALGAE (exclusive of diatoms) AND RELATIVE NUMERICAL ABUNDANCE IN SILVER BOW CREEK AND CLARK FORK, MONTANA [A=Abundant (61-100%), VC=Very Common (31-60%), C=Common (6-30%), 0=Occasional (1-5%), and R=Rare (<1%)]

	Stations				
	Impact			Recovery	
	026	024	021	023	025
Chlorophyta					
Colonies			R		
Volvocales					
Chlamydomonas spp.			R		
Chlorogonium spp.		R	R		
Chlorococcales					
Oocystis spp.				R	
Scenedesmus spp.			R		R
Scenedesmus bijuga			R	R	R
Scenedesmus quadricauda				R	0
Scenedesmus obliquus	R	R	R	R	R
Scenedesmus denticulatus				R	
Scenedesmus abundans				R	0
Scenedesmus dimorphus				R	
Pediastrum boryanum				R	0
Pediastrum duplex				0	0
Ulotrichales					
Hormidium spp.	R		R		
Chaetophorales					
Stigeoclonium spp.	0	0	A		
Zygnematales					
Cosmarium spp.				R	R
Cryptophyta					
Cryptomonadaceae					
Cryptomonas ovata				R	
Rhodomonas minuta var. *nannoplanctica*	R	R		R	R
Chrysophyta					
Chromulinales					
Phaeodermatium rivulare	A	A		0	
Cyanophyta					
Oscillatoriales					
Lyngbya aerugineo-caerulea		R		0	A
Oscillatoria spp.					0
Phormidium spp.	R	R		A	C
Miscellaneous					
Monads < 10 um	R	R	0	R	R
Single cells	R	R	0	R	0

TABLE 19. COMMON ATTACHED DIATOM AND NONDIATOM TAXA OBSERVED IN SILVER BOW CREEK AND CLARK FORK, MONTANA. (Percent contribution of each taxon to total diatom and nondiatom abundance shown in parentheses).

Station	Diatoms	Nondiatoms		
		Greens	Blue-greens	Chrysophytes
026	*Navicula arvensis* (94)	*Stigeoclonium* spp. (6)		*Phaeodermatium rivulare* (93)
024	*Navicula arvensis* (94)			*Phaeodermatium rivulare* (98)
021	*Navicula arvensis* (93)	*Stigeoclonium* spp. (91)		
023	*Nitzschia palea* (72)		*Phormidium* sp. (91)	
	Achnanthes minutissima (7)			
	Fragilaria vaucheriae (5)			
025	*Achnanthes minutissima* (45)		*Lyngbya aerugineo-carulea* (69)	
	Nitzschia palea (24)		*Phormidium* sp. (15)	
	Gomphonema parvulum (8)			
	Fragilaria vaucheriae (7)			

diatom diversity for the three stations was 0.5266. The dominant nondiatom species at stations 026 and 024 was a chrysophyte, Phaeodermatium rivulare. This species was replaced at station 024 by a green alga, Stigeoclonium tenue (Table 19).

This zone was characterized by high levels of arsenic, cadmium, and chromium. The concentrations of arsenic exceeded the EPA acute water quality criteria recommended for aquatic life at two of the three stations within this zone while cadmium exceeded the criteria levels based on hardness at all three sites (Figure 5).

Recovery Zone (Stations 023 and 025)--Diatom species diversity increased (Table 20) and species composition changed in this zone. The dominant diatom species were Achnanthes minutissima, Nitzschia palea, Fragilaria vaucheriae, and Gomphonema parvulum. Navicula arvensis was present, but in much lower abundance than in the impact zone. The non-diatom species also changed from the chrysophyte and green community in the impact zone to dominance by the blue-greens, Phormidium and Lyngbya aerugineo-carulea.

A one-way ANOVA was used to test differences at each station with respect to total number of diatom taxa, total diatom abundance (cells/mm^2), and mean Shannon-Wiener diversity (Table 20). Significant differences ($p = 0.05$) between stations were found with respect to each of the three parameters. Patterns of difference among stations were tested using SNK multiple range procedure. The total number of taxa in the recovery zone (stations 023 and 025) was significantly higher ($p = 0.05$) than in the impact zone. Species diversity was significantly lower ($p = 0.05$) in the impact zone than the recovery zone. No clear cut impact to recovery zone change was observed with cell abundances.

Certain species such as Cyclotella meneghiniana, Achnanthes minutissima, Navicula arvensis, Nitzschia palea, Surirella angustata, and Surirella ovata were observed at all stations, suggesting a wide ecological tolerance for these species. Several species occurred at both stations in the recovery zone but were not observed in the impact zone stations, including: Fragilaria vaucheriae, F. crotonenis var. oregona, F. leptostauron var. dubia, and Navicula pupula. Melosira varians was the only species occurring in each of the impact zone stations that was absent from the recovery zone.

A summary of the Silver Bow periphyton data shows that ambient concentrations of arsenic, cadmium, and chromium were above EPA water quality criteria recommended for local aquatic life at several stations. Species diversity, species richness, and composition at these stations varied substantially. Navicula arvensis was the overwhelming dominant in the impact zone stations. The recovery zone showed a more even distribution of diatom species, higher species diversity, and a higher species richness. N. arvensis was present in the recovery zone in low relative abundance being replaced by Nitzschia palea and Achnanthes minutissima. The nondiatom species also showed changes between two zones. Phaeodermatium rivulare and Stigeoclonium spp. were the dominants in the impact zone stations while the blue-greens, including Phormidium and Lyngbya aerugineo-carulea, appeared in greater abundances in the downstream recovery zone.

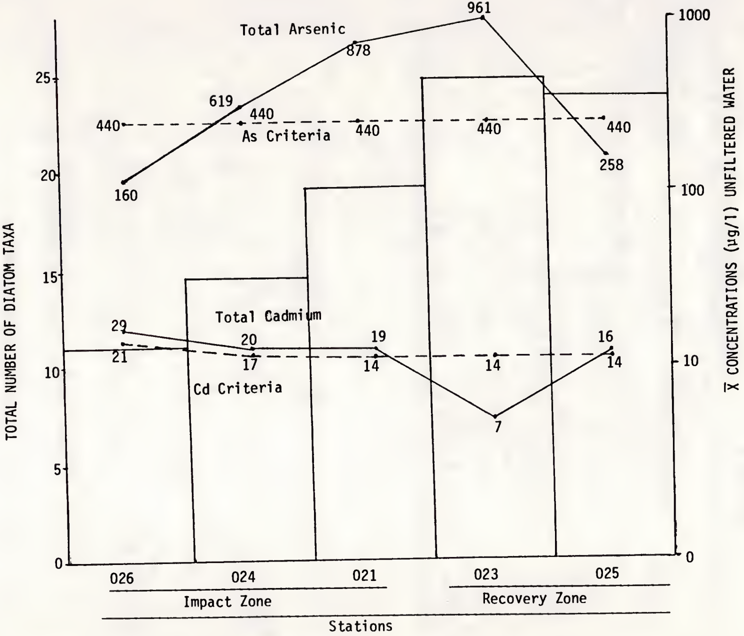


Figure 5 . Comparison of diatom species richness, mean concentrations of total arsenic and cadmium, and calculated arsenic and cadmium criteria.

TABLE 20. STUDENT-NEWMAN-KEULS STEPWISE MULTIPLE RANGE TEST (SNK) OF NUMBER OF DIATOM TAXA, SHANNON-WIENER DIVERSITY, AND TOTAL DIATOM COUNTS (cells/mm^2) AT EACH STATION IN SILVER BOW CREEK AND CLARK FORK, MONTANA. Nonsignificant ($p = 0.05$) subsets of group means are indicated by vertical lines.

	Station	Number of Taxa		Diversity		Diatom Abundance (cells/mm^2)	
		$\overline{X}$	SNK	$\overline{X}$	SNK	$\overline{X}$	SNK
Impact	026	11.0		0.5186	│	10.74	│
Impact	024	14.5		0.4675	│	9.00	│
Impact	021	19.0		0.5937	│	7.85	│
Recovery	023	24.5	│	1.8528		7.96	│
Recovery	025	23.5	│	2.3741		7.77	

Macrophyte Tissues--

Of the six metals that exceeded EPA recommended criteria, cadmium, chromium, copper, and zinc concentrations were measured in root, leaves and stems, and whole plant samples (Appendix D). Analysis of tissue data indicated no significant differences between the upstream (026, 024, 021) and downstream (023, 025) stations in Silver Bow Creek and Clark Fork River for either root or leaves and stems. Cadmium, copper, and zinc showed some trends towards decreased metal concentrations in whole plant samples at station 023 as compared to station 024 upstream. Mean cadmium and zinc concentrations at 025 were approximately one-third those at 024, with no overlap of 95% confidence limits around the means.

Although there was generally a lack of significant differences in tissue metal concentrations among stations, sample concentrations can be compared to studies from other contaminated areas. For example, Mudroch and Capobianco (1979) examined aquatic macrophyte tissues growing in waters receiving mine effluents. They found *Myriophyllum verticulatum*, *Elodea canadensis*, *Scirpus* sp., and *Typha* sp. tissues contained 10-19 µg/g copper and 14-40 µg/g zinc. Macrophytes (Juncaceae) from Silver Bow Creek and Clark Fork River contained whole plant copper concentrations from 216.4 µg/g to 879.0 µg/g in the downstream recovery zone. Zinc concentrations in whole plant tissues ranged from 210.9 µg/g in the downstream station (023) to 1946.7 µg/g upstream from the sedimentation ponds (024). Plant tissue metal concentrations have also been found to relate to metal concentrations in sediments, as well as to ambient water levels (Mudroch and Capobianco 1979). The elevated sediment zinc and copper concentrations in the study area (Table 14) are probably largely responsible for the higher plant tissue accumulation.

Fish

Community Census--

Fish were primarily collected in this study to analyze tissue metal concentrations. However, the following species in Silver Bow Creek and Clark Fork were reported from qualitative observations and fish collections during electroshocking: longnose sucker (*Catostomus catostomus*), rainbow trout (*Salmo gairdneri*), brown trout (*Salmo trutta*), various chubs and minnows (Cyprinidae), and white sucker (*Catostomus commersonii*).

Recent studies have indicated that improvements in the Anaconda Warm Springs facilities, coupled with water quality improvement in Silver Bow Creek, have led to the reestablishment of a fish population downstream from the Anaconda ponds (Peckham 1979). Prior to 1969, no fish species were collected during a two year study by the Montana Fish and Game (Peckham 1979). By the spring of 1974, a substantial population of brown trout and other game fish was reported in the Clark Fork River. Additional reductions in pollutant contributions may be necessary before Silver Bow Creek will support game fish upstream from the Anaconda ponds.

Tissues--

The distribution and relative abundance of fish in Silver Bow Creek and Clark Fork River were highly variable. Tissues from several fish species were collected and analyzed at each station; species selection depended upon their presence and abundance at each station.

Individual fish tissues were analyzed for metal content (Appendix D) to determine susceptibility of various tissues to metal accumulation. Tissues analyzed included liver, kidney, gill, muscle, brain, and eye.

The fact that acute criteria for several metals were exceeded at stations in the impact zone, sedimentation pond, and downstream recovery zone (Table 8) indicates that no real unimpacted environment was sampled in Silver Bow Creek or Clark Fork for controlled comparisons. This situation is also reflected in the fish tissue samples (Appendix D) which show little evidence of bio-accumulation of metals above control zone values. Both zinc and copper show some up- to downstream increasing trends; however, 95% confidence intervals around mean metal concentrations in the fish tissues show considerable overlap among stations, indicating no significant ($p = 0.05$) differences between them. Some of this overlap may be attributable to species variation within the tissue samples, but there were insufficient data for this to be statistically verified.

Of the six metals which exceeded ambient criteria concentrations, arsenic and selenium were not analyzed in fish tissues from Silver Bow Creek. Chromium and cadmium data were generally very sparse and below instrument detection limits so are not included in Appendix D.

Copper concentrations were highest in liver tissue, followed by kidney and gill tissues, and lowest in muscle. Concentrations in muscle tissue samples from Silver Bow Creek were generally comparable to those reported for arctic char (*Salvelinus alpinus*) by Bohn and Fallis (1978). Liver copper levels in Silver Bow Creek, however, were several times higher than the 1978 study.

Zinc concentrations in Silver Bow Creek and Clark Fork fish were similarly high for eye, brain, gill, and liver tissues, and lowest in the muscle. Andreasen (1981) also found that salmonid fishes in the Red River, New Mexico, accumulated zinc in gill, kidney, and especially liver tissues, even in low ambient water exposures. As with copper, muscle tissue contained zinc levels comparable to Bohn and Fallis (1978), but liver zinc concentrations tended to be higher than their study, especially in the downstream sites. Mount (1964), in a three month accumulation study with bluegill, found "extremely large increases in the zinc concentrations in the whole gill and comparatively small increases in all other tissue."

Bioassays--

Bioassays were conducted at the ERL-Duluth laboratory on water from stations 021 and 023. In these analyses, no toxic response was observed at either station using the fish ventilation index (Appendix E). Results from the enzyme inhibition test indicated a positive response for both stations 021 and 023. This experimental test is based upon the theoretical premise that certain aquatic toxicants inhibit the catalytic activity (=positive response) of acetycholinesterase (AChE) and/or urease (*in vitro*). The *Daphnia* and algal toxicity tests showed a positive response only for water from station 021.

Because of the presence of multiple contaminants in many river systems, a toxic response to one of the bioassay tests is not necessarily conclusive

evidence of metal toxicity. For this reason, with the daphniid and algal tests, EDTA was added to samples showing toxicity to complex the resident metals. Reduced toxicity was evidence that metals were the source of toxicity. In Silver Bow Creek, both the *Daphnia* and algal tests had reduced toxicity when EDTA was added.

Results from steelhead trout and *Daphnia* bioassays at ERL-Corvallis showed 0% trout mortality and 5% mortality for *Daphnia* in water from station 021. Copper was the main metal reported in concentrations exceeding acute criteria levels; 0.45 m filtration decreased the copper levels to below the criterion for protection against acute toxicity. A high proportion of the zinc was also tied up in particulate matter. However, in both the filtered and total samples, copper, cadmium, and zinc exceeded the 24-hour mean criterion values, suggesting that some chronic toxicity should be occurring to sensitive biota in Silver Bow Creek (Chapman unpublished data).

Algal assay tests to determine the growth potential of *Selenastrum capricornutum* in water from Silver Bow Creek and Clark Fork showed algal growth was not inhibited by toxic constituents in Clark Fork (023). Growth was significantly inhibited (50%) with a solution containing 55% water from Silver Bow Creek (021). There was no inhibition of growth at 25% concentration, nor was Silver Bow Creek water lethal to algae cultured for 120 hours in full strength solution (Green and Merwin 1980).

CONCLUSIONS

1. Concentrations of total arsenic, cadmium, chromium, copper, selenium, and zinc concentrations exceeded EPA recommended acute criteria at one or more stations in Silver Bow Creek and Clark Fork River. In general, metal concentrations tended to be higher in Silver Bow Creek and the Anaconda ponds than downstream in Clark Fork River. The results are consistent with other literature which has reported metal concentrations in the study area at levels potentially toxic to aquatic life.

2. There was a substantial improvement in macroinvertebrate and periphyton community health, as measured by various biological indices, at stations in Clark Fork River downstream from the Anaconda Settling ponds at Warm Springs. These data suggest that the Anaconda Ponds are acting as an effective "sink" for suspended solids and associated metals being carried downstream to the ponds from upstream mining activities.

3. Other biological parameters, such as plant and fish tissue metal bioaccumulation, were not clear indicators of metal impact and recovery in the study area.

4. Bioassay results from the Clark Fork River and Silver Bow Creek suggest that metals, particularly copper, primarily account for the toxicity observed to resident biological communities.

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APPENDIX A

WATER CHEMISTRY SUMMARY DATA

Metal data presented include both grab samples and ISCO collections. Grab sample data are presented first at the start of each station, typically 6 data points (3 mid-depth grabs, 2 analytical replicates). ISCO data, as average composites over time, follow.

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

02026231
46 03 00.0 112 47 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574544-0083841

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00610 UN-IONZD NH3-N MG/L	00625 KJELDL N Total MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/08/09	11 00	0000	14.8	1950	10.2	8.40	83	1146	67	1.200	0.710	1.70
	11 01	0000					83	1086	38		0.690	1.60
	11 02	0000					86	1175	33	1.100	0.680	6.60
	11 03	0000					85	1191	34	0.940	0.690	6.40
	11 04	0000					86	1164	66	1.190	0.630	3.70
	11 05	0000					84	1162	22	1.340	0.660	3.70
	11 10	0000	14.8	1920	10.6	8.32						
	11 20	0000	14.8	1920	10.5	8.29						
	11 30	0000	14.9	1890	10.6	8.26						
	11 40	0000	14.9	1890	10.6	8.25						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU	70507 ORTHOPO4 PO4 MG/L	00720 CYANIDE CN-TOT MG/L	00916 CALCIUM CA-TOT MG/L	00915 CALCIUM CA,DISS MG/L
80/08/09	11 00	0000	0.040	12.1	0.40	0.07	10.1	0.04	0.011	250.0	245.0
	11 01	0000	0.040	13.0				0.04			
	11 02	0000	0.030					0.06		248.0	248.0
	11 03	0000	0.030					0.06			
	11 04	0000	0.030					0.05		245.0	242.0
	11 05	0000	0.030					0.04			
	11 10	0000			0.48	0.06	9.5			246.0	245.0
	11 20	0000					10.1			245.0	249.0
										251.0	251.0
										261.0	
										259.0	

STORET RETRIEVAL DATE 82/02/01

02024231
46 04 00.0 112 48 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE
11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574542-0083837

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00610 UN-IONZD NH3-N MG/L	00625 KJELDL N Total MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/08/07	11 30	0001	14.9	1410	11.0	8.37	88	994	25	0.880	0.550	8.60
	11 31	0000					90	1603	90	0.920	0.420	8.50
	11 32	0000					86	965	102	0.940	0.630	21.20
	11 33	0000					86	985	51	0.600	0.500	21.60
	11 34	0000					88	989	29	0.450	0.450	6.90
	11 35	0000					88	946	292	0.560	0.450	7.10
	11 40	0000	14.8	1390	11.6	8.39						
	11 50	0000	14.8	1380	11.8	8.40						
	12 00	0000	14.8	1400	11.6	8.40						
	12 10	0000	14.8	1390	11.7	8.39						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU	70507 ORTHOPO4 PO4 MG/L	00720 CYANIDE CN-TOT MG/L	00916 CALCIUM CA-TOT MG/L	00915 CALCIUM CA,DISS MG/L
80/08/07	11 30	0001	0.050	10.2	0.50	0.06	14.0	0.11	0.011	196.0	192.0
	11 31	0000	0.050	14.2				0.11			
	11 32	0000	0.100					0.08			
	11 33	0000	0.100							196.0	193.0
	11 34	0000	0.040					0.08			
	11 35	0000	0.040					0.04			
	11 40	0000			0.70	0.06	13.5			194.0	193.0
	11 50	0000			0.60	0.06	13.5	0.04			
										197.0	195.0
										194.0	195.0
										197.0	194.0
										204.0	
										206.0	

STORET RETRIEVAL DATE 82/02/01

02021131
46 07 00.0 112 47 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE 11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574540-0083833

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00610 UN-IONZD NH3-N MG/L	00625 KJELDL N Total MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/08/03	10 00	0000	12.1	1530	10.0	7.63	94	839	3	0.141	0.370	1.10
	10 01	0000					94	834	33	0.490	0.290	1.20
	10 02	0000					94	817	10	0.150	0.370	1.40
	10 03	0000					92	872	18	0.144	0.310	1.50
	10 04	0000					96	800	9	0.110	0.340	1.90
	10 05	0000					93	909	26	0.104	0.290	1.90
	10 10	0000	12.2	1530	9.8	7.53						
	10 20	0000	12.2	1440	11.0	7.54						
	10 30	0000	12.3	1440	11.2	7.59						
	10 40	0000	12.2	1440	11.0	7.64						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU	70507 ORTHOPO4 PO4 MG/L	00720 CYANIDE CN-TOT MG/L	00916 CALCIUM CA-TOT MG/L	00915 CALCIUM CA,DISS MG/L
80/08/03	10 00	0000	0.030	6.8	0.45	0.06	8.5		0.003	164.0	163.0
	10 01	0000	0.030	11.0				0.03			
	10 02	0000	0.030					0.03		164.0	166.0
	10 03	0000	0.040					0.03			
	10 04	0000	0.040					0.03		165.0	164.0
	10 05	0000	0.030					0.03			
	10 10	0000			0.90	0.06	8.3			166.0	166.0
	10 20	0000			0.75		7.9			164.0	164.0
										164.0	165.0
										168.0	
										168.0	

STORET RETRIEVAL DATE 82/02/01

02027521
46 11 00.0 112 46 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574545-0083843

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PRCBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00610 UN-IONZD NH3-N MG/L	00625 KJELDL N Total MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/08/11	15 20	0000	20.4	1640	7.6	9.42						
	15 30	0000	19.7	1640	7.1	9.29	29	948	22	0.055	0.370	0.24
	15 31	0000					30	959	21	0.047	0.370	0.24
	15 32	0000					30	973	14	0.056	0.340	0.96
	15 33	0000					31	974	27	0.050	0.340	0.94
	15 34	0001					32	986	58	0.084	0.290	0.17
	15 35	0001					33	948	33	0.088	0.260	0.17
	15 40	0000	18.9	1640	6.8	9.34						
	15 50	0001	18.8	1620	6.3	9.36						
	16 00	0001	18.8	1640	6.6	9.34						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLOPINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU	70507 ORTHOPO4 PO4 MG/L	00720 CYANIDE CN-TOT MG/L	00916 CALCIUM CA-TOT MG/L	00915 CALCIUM CA,DISS MG/L
80/08/11	15 20	0000			0.60	0.06	1.5			206.0	198.0
	15 30	0000	0.010		0.60	0.06	1.5			214.0	198.0
	15 31	0000	0.000							189.0	206.0
	15 32	0000	0.010							192.0	208.0
	15 33	0000	0.010							200.0	195.0
	15 34	0001	0.020					0.01	0.010		
	15 35	0001	0.020							203.0	198.0
	15 40	0000					1.7	0.01			
								0.01			
								0.01			
								0.01			
								0.005			

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

02023131
46 11 00.0 112 46 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574541-0083835

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00610 UN-IONZD NH3-N MG/L	00625 KJELDL N Total MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/08/04	12 45	0000	16.8	1200	8.1	8.30	79	780	3	0.097	0.260	0.14
	12 46	0000					74	915	4	0.087	0.240	0.14
	12 47	0000					80	792	1	0.077	0.290	0.14
	12 48	0000					74	755	27	0.071	0.240	0.14
	12 49	0000					74	780	21	0.085	0.260	0.21
	12 50	0000					74	773	29	0.077	0.210	0.20
	12 55	0000	16.8	1200	8.5	8.20						
	13 00	0000	16.8	1160	8.8	8.10						
	13 10	0000	16.8	1150	8.7	8.10						
	13 20	0000	16.8	1140	8.9	8.10						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU	70507 ORTHOPO4 PO4 MG/L	00720 CYANIDE CN-TOT MG/L	00916 CALCIUM CA-TOT MG/L	00915 CALCIUM CA,DISS MG/L
80/08/04	12 45	0000	0.010	8.6	0.90	0.06	1.5	0.01	0.014	155.0	154.0
	12 46	0000	0.010	12.5				0.01			
	12 47	0000	0.010					0.01		157.0	156.0
	12 48	0000	0.010					0.01			
	12 49	0000	0.010					0.01		156.0	155.0
	12 50	0000	0.010					0.01			
	12 55	0000			0.90	0.06	1.5			156.0	156.0
	13 00	0000			0.90	0.06	1.5			155.0	152.0
	13 10	0000			0.90	0.06	1.5			156.0	154.0
	13 20	0000			0.90	0.06	1.5				

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

02025231
46 16 00.0 112 45 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574543-0083839

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00610 UN-IONZD NH3-N MG/L	00625 KJELDL N Total MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/08/08	10 00	0000	15.4	1260	8.4	7.95	97	754	0	2.000	0.260	0.55
	10 01	0000					98	749	16	0.002	0.210	0.54
	10 02	0000					92	752	2	0.042	0.210	1.70
	10 03	0000					94	740	9	0.028	0.180	1.70
	10 04	0000					91	741	19	0.068	0.210	0.31
	10 05	0000					95	746	61	0.056	0.210	0.30
	10 10	0000	15.4	1260	8.4	7.92						
	10 20	0000	15.5	1220	8.6	7.85						
	10 30	0000	15.4	1220	8.5	7.80						
	10 40	0000	15.5	1210	8.5	7.73						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU	70507 ORTHOPO4 PO4 MG/L	00720 CYANIDE CN-TOT MG/L	00916 CALCIUM CA-TOT MG/L	00915 CALCIUM CA,DISS MG/L
80/08/08	10 00	0000	0.010		0.60	0.06	1.4	0.05	0.012	141.0	140.0
	10 01	0000	0.020					0.05			
	10 02	0000	0.020					0.01		142.0	139.0
	10 03	0000	0.010					0.01			
	10 04	0000	0.010					0.01		142.0	141.0
	10 05	0000	0.010					0.01			
	10 10	0000			0.50	0.06	1.3			142.0	141.0
	10 20	0000					1.4			141.0	140.0
										140.0	142.0
										150.0	
										150.0	
										154.0	
										154.0	

STORET RETRIEVAL DATE 82/02/01

02026231
46 03 00.0 112 47 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574544-0083841

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01040 COPPER CU,DISS UG/L	01042 COPPER CU,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L
80/08/09	11 00	0000	21	27	69	303	311	305	39.0	43.0	756	1680
	11 02	0000	18	25	71	301	222	258	30.0	56.0	763	1700
	11 04	0000	17	23	69	326	254	275	29.0	57.0	435	1660
	11 06	0000	25	18	73	323	262	224	45.0	49.0	449	1680
	11 08	0000	27	24	76	327	311	264	50.0	49.0	470	1730
	11 10	0000	26	24	79	339	373	264	77.0	31.0	476	1780
	11 01											
CP(T)-03	AVE	0000		45		427		379		62.0		1840
80/08/09	13 01											
	12 01											
CP(T)-03	AVE	0000		46		420		454		54.0		1860
80/08/09	14 01											

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L	01030 CHROMIUM CR,DISS UG/L	01034 CHROMIUM CR,TOT UG/L	01145 SELENIUM SE,DISS UG/L	01147 SELENIUM SE,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01105 ALUMINUM AL,TOT UG/L	01106 ALUMINUM AL,DISS UG/L
80/08/09	11 00	0000	1300	160	32	29		151		12	2530	2330
	11 02	0000			29	31						
	11 04	0000			28	29		42			2390	2260
	11 06	0000			34	26						
	11 08	0000			37	31					2530	2320
	11 10	0000			41	29						
	11 01										2360	2190
CP(T)-03	AVE	0000				41					2620	2320
80/08/09	13 01										2510	2280
	12 01											
CP(T)-03	AVE	0000				44					2720	
80/08/09	14 01											
											2620	

STORET RETRIEVAL DATE 82/02/01

02024231
46 04 00.0 112 48 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574542-0083837

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01040 COPPER CU,DISS UG/L	01042 COPPER CU,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L
80/08/07	11 30	0001	8	12	46	370	175	187	16.0	11.0	64	819
	11 32	0001	4	13	41	368	81	147	13.0	25.0	61	831
	11 34	0001	13	14	129	376	236	215	33.0	28.0	416	827
	11 36	0001	14	9	130	376	224	100	25.0	19.0	425	839
	11 38	0001	17	10	47	358	254	153	31.0	16.0	124	811
	11 40	0001	16	9	51	365	241	149	35.0	4.0	122	824
	11 31											
CP(T)-03	AVE	0001		44		380		262		36.0		882
80/08/07	13 31											
	12 31											
CP(T)-03	AVE	0001		47		385		262		39.0		891
80/08/07	14 31											

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L	01030 CHROMIUM CR,DISS UG/L	01034 CHROMIUM CR,TOT UG/L	01145 SELENIUM SE,DISS UG/L	01147 SELENIUM SE,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01105 ALUMINUM AL,TOT UG/L	01106 ALUMINUM AL,DISS UG/L
80/08/07	11 30	0001	659	1100	15	18	130	144	33	68	2250	2020
	11 32	0001			13	16						
	11 34	0001	481	1050	19	19	122	163	45	76		
	11 36	0001			21	13					2130	1890
	11 38	0001	465	48	25	13	92	85	26	58		
	11 40	0001			25	13						
	11 31										2280	1990
CP(T)-03	AVE	0001		279		24		180		23		
80/08/07	13 31										2180	1940
	12 31										2300	2090
CP(T)-03	AVE	0001				25					2200	1880
80/08/07	14 31											
											2370	
											2320	

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

02021131
46 07 00.0 112 47 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574540-0083833

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01040 COPPER CU,DISS UG/L	01042 COPPER CU,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L
80/08/03	10 00	0000	4	9	50	357	83	149	28.0	25.0	57	728
	10 02	0000	7	10	49	354	81	141	22.0	18.0	58	733
	10 04	0000	5	6	75	357	26	92	29.0	22.0	492	727
	10 06	0000	6	7	73	354	26	62	23.0	17.0	498	736
	10 08	0000	7	6	63	360	100	53	22.0	31.0	74	727
	10 10	0000	9	4	69	358	126	51	19.0	30.0	73	737
	10 01											
CP(T)-03	AVE	0000		53		304		205		23.0		653
80/08/03	12 01											
	11 01											
CP(T)-03	AVE	0000		57		298		209		21.0		659
80/08/03	13 01											

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L	01030 CHROMIUM CR,DISS UG/L	01034 CHROMIUM CR,TOT UG/L	01145 SELENIUM SE,DISS UG/L	01147 SELENIUM SE,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01105 ALUMINUM AL,TOT UG/L	01106 ALUMINUM AL,DISS UG/L
80/08/03	10 00	0000	1150	1350	15	19	78	94	53	61	2230	1880
	10 02	0000		238	18	22		39				
	10 04	0000	640	1420	13	18	133	169	45	67	2090	1810
	10 06	0000			15	16						
	10 08	0000	571	1140	16	16	28	82	55	62	2270	1960
	10 10	0000			19	18						
	10 01										2110	1830
CP(T)-03	AVE	0000		1110		22		215		83	2270	1950
80/08/03	12 01										2110	1740
	11 01											
CP(T)-03	AVE	0000		11		18					2140	
80/08/03	13 01											
											1970	

STORET RETRIEVAL DATE 82/02/01

02027521
46 11 00.0 112 46 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE
11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574545-0083843

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01040 COPPER CU,DISS UG/L	01042 COPPER CU,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L
80/08/11	15 20	0001	11	20	19	62	198	328	25.0	60.0	54	670
	15 22	0001	7	17	14	60	164	224	16.0	57.0	50	691
	15 24	0001	15	15	14	12	264	283	31.0	34.0	51	67
	15 26	0001	14	13	20	17	271	247	36.0	42.0	48	62
	15 28	0001	15	14	24	24	266	258	29.0	32.0	53	171
	15 30	0001	15	12	22	29	275	281	24.0	37.0	50	174

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L	01030 CHROMIUM CR,DISS UG/L	01034 CHROMIUM CR,TOT UG/L	01145 SELENIUM SE,DISS UG/L	01147 SELENIUM SE,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01105 ALUMINUM AL,TOT UG/L	01106 ALUMINUM AL,DISS UG/L
80/08/11	15 20	0001	2360		22	43	272		174		2130	2250
	15 22	0001	817		18	41	27		18		2120	2020
	15 24	0001	2650	4780	29	22	237	583	174	302	2280	2030
	15 26	0001	636	2250	24	24	97	179	22	138	2120	1920
	15 28	0001	2070	1930	26	24	294	285	130	196	2320	2190
	15 30	0001	185	1350	22	25	13	169		90		
											2150	2060

STORET RETRIEVAL DATE 82/02/01

02023131
46 11 00.0 112 46 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE
11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574541-0083835

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01040 COPPER CU,DISS UG/L	01042 COPPER CU,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L
80/08/04	12 45	0000	5	9	21	30	98	202	40.0	34.0	80	113
	12 47	0000	4	9	19	34	66	141	26.0	39.0	79	114
	12 49	0000		8	18	30	32	134	24.0	27.0	96	115
	12 51	0000	4	8	22	31	83	96	29.0	27.0	98	111
	12 53	0000	5	5	22	28	94	92	16.0	22.0	83	111
	12 55	0000	8	5	23	28	173	77	26.0	17.0	85	110

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L	01030 CHROMIUM CR,DISS UG/L	01034 CHROMIUM CR,TOT UG/L	01145 SELENIUM SE,DISS UG/L	01147 SELENIUM SE,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01105 ALUMINUM AL,TOT UG/L	01106 ALUMINUM AL,DISS UG/L
80/08/04	12 45	0000	875	1110	24	29	22	174	46	77	1920	1950
	12 47	0000			25	28						
	12 49	0000	515	845	22	29	86	171	26	53	1850	1700
	12 51	0000			25	25	40					
	12 53	0000	624	928	24	25	37	162	37	57	1930	1890
	12 55	0000			26	26						
											1850	1800
											1950	1880
											1850	1730

STORET RETRIEVAL DATE 82/02/01

02025231
46 16 00.0 112 45 00.0 5
BUTTE MONTANA SILVER BOW DEER LODGE CTYS CLARK F
30023 MONTANA DEER LOODGE
PACIFIC NORTHWEST 130200
CLARK FORK PEND ORIELLE RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574543-0083839

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01040 COPPER CU,DISS UG/L	01042 COPPER CU,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L
80/08/08	10 00	0000	6	9	24	27	117	211	27.0	18.0	83	97
	10 02	0000	9	14	25	33	151	207	27.0	26.0	85	99
	10 04	0000	9	9	21	29	143	173	26.0	28.0	94	98
	10 06	0000	9	10	22	27	192	198	15.0	17.0	91	100
	10 08	0000	12	8	22	31	175	179	28.0	14.0	95	106
	10 10	0000	16	11	25	29	249	185	37.0	22.0	99	105
	10 01											
CP(T)-03	AVE	0000		24		26		285		39.0		94
80/08/08	12 01											
	11 01											
CP(T)-03	AVE	0000		23		24		279		21.0		96
80/08/08	13 01											
	12 01											
CP(T)-03	AVE	0000		23		29		224		39.0		131
80/08/08	14 01											
	13 01											
CP(T)-03	AVE	0000		24		32		239		34.0		138
80/08/08	15 01											

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L	01030 CHROMIUM CR,DISS UG/L	01034 CHROMIUM CR,TOT UG/L	01145 SELENIUM SE,DISS UG/L	01147 SELENIUM SE,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01105 ALUMINUM AL,TOT UG/L	01106 ALUMINUM AL,DISS UG/L
80/08/08	10 00	0000		273	25	25	42	115	17	25	1730	1720
	10 02	0000			26	31						
	10 04	0000		166	29	31	82	100	5	34	1570	1570
	10 06	0000			26	25						
	10 08	0000	454	521	28	28	53	77	14	18	1770	1700
	10 10	0000			34	31						
	10 01										1540	1510
CP(T)-03	AVE	0000		230		32		103		21	1680	1630
80/08/08	12 01										1470	1540
	11 01											
CP(T)-03	AVE	0000				31					1600	
80/08/08	13 01											
	12 01											
CP(T)-03	AVE	0000		104		32		37			1430	
80/08/08	14 01											
	13 01											
CP(T)-03	AVE	0000				35					1590	
80/08/08	15 01											
											1450	

APPENDIX B

MACROINVERTEBRATE CENSUS DATA

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 9, 1980
STATION: GREGSON HOT SPRINGS, SILVER BOW CREEK U.S. SED. PONDS (026) SUBSTATION: 221
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: RALPH PUCKETT (61)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
EPHEMEROPTERA					
BAETIDAE					
BAETIS SPP. (1230)	1 - 3	1.	5.	0.	6.
PLECOPTERA					
PERLIDAE					
DORONEURIA THEODORA (3600)	1 - 3	0.	1.	0.	1.
PERLODIDAE					
ISOPERLA SPP. (3810)	1 - 3	1.	0.	0.	1.
TRICHOPTERA					
RHYACOPHILIDAE					
RHYACOPHILA SPP. (8630)	1 - 3	1.	2.	3.	6.
DIPTERA					
CHIRONOMIDAE					
-ALL- (10510)	1 - 3	21.	8.	36.	65.
CHIRONOMIDAE, S-FAMILY-CHIRONOMINAE					
-ALL- (12110)	1 - 3	1.	0.	0.	1.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	387.	326.	434.	1147.
CULICIDAE					
CULEX SP. (17870)	1 - 3	1.	0.	1.	2.
EMPIDIDAE					
-ALL- (18210)	1 - 3	0.	0.	1.	1.
RHAGIONIDAE					
ATHERIX VARIEGATA (18710)	1 - 3	1.	0.	2.	3.
COLEOPTERA					
ELMIDAE					
OPTIOSERVUS QUADRIMACULATUS (19930)	1 - 3	2.	1.	2.	5.
DYTISCIDAE					
AGABUS SP. (20455)	1 - 3	1.	0.	0.	1.
-ALL- (20490)	1 - 3	0.	0.	3.	3.
HALIPLIDAE					
BRYCHIUS SP. (20660)	1 - 3	0.	2.	0.	2.
HYDRACARINA					
SPERCHONIDAE					
SPERCHON SP. (21510)	1 - 3	1.	0.	0.	1.
TOTAL FOR 15 SPECIES BY REPLICATE:	1 - 3	418.	345.	482.	

TOTAL FOR 3 REPLICATES, 15 SPECIES: 1245.

PROJECT: TOXIC METALS PROJECT (TM)   AREA: SILVER BOW CREEK, MONTANA (02)   DATE: AUGUST 7, 1980
STATION: ANACONDA RD. AT CRACKERVILLE BRIDGE U.S. SED. PONDS (024)   SUBSTATION: 221
SAMPLER TYPE: BOX SAMPLER - 30 MESH NET (15)
NUMBER OF REPLICATES: 5   FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS					TOTAL FOR SP.
TRICHOPTERA							
HYDROPSYCHIDAE							
HYDROPSYCHE SPP. (6560)	1 - 5	1.	0.	0.	0.	0.	1.
HYDROPTILIDAE							
STACTOBIELLA SP. (7760)	1 - 5	1.	0.	0.	0.	0.	1.
DIPTERA							
CHIRONOMIDAE							
-ALL- (10510)	1 - 5	7.	9.	2.	11.	6.	35.
CHIRONOMIDAE, S-FAMILY TANYPODINAE							
-ALL- (10610)	1 - 5	2.	0.	0.	1.	0.	3.
CHIRONOMIDAE, S-FAMILY-CHIRONOMINAE							
-ALL- (12110)	1 - 5	0.	0.	0.	0.	1.	1.
CHIRONOMIDAE, TRIBE TANYTARSINI							
-ALL- (13510)	1 - 5	1.	0.	0.	0.	0.	1.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE							
-ALL- (14110)	1 - 5	54.	63.	70.	37.	58.	282.
CORYNONEURA/THIENEMANNIELLA COMPLEX (14410)	1 - 5	0.	0.	0.	1.	0.	1.
EMPIDIDAE							
-ALL- (18210)	1 - 5	1.	0.	0.	0.	0.	1.
COLEOPTERA							
ELMIDAE							
HETERLIMNIUS SP. (19860)	1 - 5	1.	0.	0.	2.	0.	3.
OPTIOSERVUS QUADRIMACULATUS (19930)	1 - 5	0.	1.	0.	0.	0.	1.
DYTISCIDAE							
AGABUS SP. (20455)	1 - 5	1.	1.	0.	0.	0.	2.
LIODESSUS/OREODYTES SP. (20485)	1 - 5	1.	1.	1.	2.	1.	6.
-ALL- (20490)	1 - 5	2.	2.	2.	1.	0.	7.

TOTAL FOR 14 SPECIES BY REPLICATE:	1 - 5	72.	77.	75.	58.	66.
TOTAL FOR 5 REPLICATES, 14 SPECIES:		345.				

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 5, 1980
STATION: 1 MILE UPSTREAM OF ANACONDA FISH AND WILDLIFE PONDS (021) SUBSTATION: 11
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (8)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
TRICHOPTERA					
HYDROPSYCHIDAE					
HYDROPSYCHE SPP. (8560)	1 - 3	4.	0.	0.	4.
DIPTERA					
CHIRONOMIDAE					
-ALL- (10510)	1 - 3	61.	37.	8.	106.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	254.	115.	74.	443.
SIMULIIDAE					
-ALL- (17510)	1 - 3	0.	0.	1.	1.
TIPULIDAE					
DICRANOTA SP. (18560)	1 - 3	1.	0.	0.	1.
PSYCHODIDAE					
PSYCHODA SP. (19250)	1 - 3	0.	1.	0.	1.
COLEOPTERA					
ELMIDAE					
OPTIOSERVUS QUADRIMACULATUS (19930)	1 - 3	7.	0.	0.	7.
CLEPTELMIS ADDENDA (20111)	1 - 3	2.	0.	0.	2.
DYTISCIDAE					
AGABUS SP. (20455)	1 - 3	5.	1.	0.	6.
LIODESSUS/OREODYTES SP. (20485)	1 - 3	1.	0.	0.	1.
-ALL- (20490)	1 - 3	12.	0.	0.	12.
HYDRACARINA					
SPERCHONIDAE					
SPERCHON SP. (21510)	1 - 3	2.	1.	0.	3.
OLIGOCHAETA					
-ALL- (59010)	1 - 3	1.	2.	0.	3.
TOTAL FOR 13 SPECIES BY REPLICATE:	1 - 3	350.	157.	83.	
TOTAL FOR 3 REPLICATES, 13 SPECIES:		590.			

PROJECT: TOXIC METALS PROJECT (TM)   AREA: SILVER BOW CREEK, MONTANA (02)   DATE: AUGUST 10, 1980
STATION: ANACONDA FISH AND WILDLIFE SEDIMENTATION PONDS (027)   SUBSTATION: 251
SAMPLER TYPE: ECKMAN DREDGE BOTTOM GRAB (60)
NUMBER OF REPLICATES: 3   FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
EPHEMEROPTERA					
BAETIDAE					
BAETIS SPP. (1230)	1 - 3	2.	0.	0.	2.
TRICHOPTERA					
LEPTOCERIDAE					
MYSTACIDES SP. (7190)	1 - 3	0.	0.	1.	1.
DIPTERA					
CHIRONOMIDAE					
-ALL- (10510)	1 - 3	0.	0.	1.	1.
CHIRONOMIDAE, S-FAMILY TANYPODINAE					
-ALL- (10610)	1 - 3	2.	0.	2.	4.
CHIRONOMIDAE, S-FAMILY-CHIRONOMINAE					
-ALL- (12110)	1 - 3	2.	2.	25.	29.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	7.	8.	11.	26.
COLEOPTERA					
HALIPLIDAE					
BRYCHIUS SP. (20660)	1 - 3	0.	0.	1.	1.
AMPHIPODA					
TALITRIDAE					
HYALELLA AZTECA (41060)	1 - 3	3.	0.	29.	32.
OLIGOCHAETA					
-ALL- (59010)	1 - 3	10.	6.	83.	99.
HIRUDINEA					
-ALL- (62510)	1 - 3	10.	0.	9.	19.
TOTAL FOR 10 SPECIES BY REPLICATE:	1 - 3	36.	16.	162.	
TOTAL FOR 3 REPLICATES, 10 SPECIES:		214.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 4, 1980
STATION: 1 MI DOWNSTREAM ANACONDA FISH AND WILDLIFE PONDS (023) SUBSTATION: 131
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
EPHEMEROPTERA					
BAETIDAE					
BAETIS SPP. (1230)	1 - 3	0.	4.	0.	4.
BAETIS BICAUDATUS (1300)	1 - 3	0.	1.	0.	1.
PLECOPTERA					
PERLODIDAE					
ISOPERLA SPP. (3810)	1 - 3	0.	0.	6.	6.
PTERONARCYIDAE					
PTERONARCELLA BADIA (4510)	1 - 3	0.	3.	7.	10.
MEGALOPTERA					
SIALIDAE					
SIALIS SP. (5790)	1 - 3	0.	0.	1.	1.
TRICHOPTERA					
HYDROPSYCHIDAE					
HYDROPSYCHE SPP. (6560)	1 - 3	6.	26.	113.	145.
CHEUMATOPSYCHE SPP. (6630)	1 - 3	0.	0.	34.	34.
LEPTOCERIDAE					
-ALL- (7200)	1 - 3	0.	0.	10.	10.
HYDROPTILIDAE					
STACTOBIELLA SP. (7760)	1 - 3	0.	7.	27.	34.
HELICOPSYCHIDAE					
HELICOPSYCHE BOREALIS (8201)	1 - 3	1.	0.	4.	5.
GLOSSOSOMATIDAE					
AGAPETUS SP. (9060)	1 - 3	0.	0.	6.	6.
DIPTERA					
CHIRONOMIDAE					
-ALL- (10510)	1 - 3	2.	12.	33.	47.
CHIRONOMIDAE, S-FAMILY TANYPODINAE					
-ALL- (10610)	1 - 3	1.	2.	70.	73.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	2.	65.	124.	191.
SIMULIIDAE					
-ALL- (17510)	1 - 3	0.	4.	4.	8.
EMPIDIDAE					
-ALL- (18210)	1 - 3	0.	0.	1.	1.

(Continued)

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 4, 1980
STATION: 1 MI DOWNSTREAM ANACONDA FISH AND WILDLIFE PONDS (023) SUBSTATION: 131
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
DIPTERA					
TIPULIDAE					
HEXATOMA SP. (18360)	1 - 3	0.	3.	2.	5.
TIPULA SP. (18410)	1 - 3	1.	0.	2.	3.
RHAGIONIDAE					
ATHERIX VARIEGATA (18710)	1 - 3	0.	2.	9.	11.
COLEOPTERA					
ELMIDAE					
ZAITZEVIA PARVULA (19770)	1 - 3	0.	1.	1.	2.
OPTIOSERVUS QUADRIMACULATUS (19930)	1 - 3	2.	21.	12.	35.
DYTISCIDAE					
LIODESSUS/DREDDTIES SP. (20485)	1 - 3	0.	0.	20.	20.
-ALL- (20480)	1 - 3	0.	2.	34.	36.
HALIPLIDAE					
BRYCHIUS SP. (20660)	1 - 3	0.	1.	0.	1.
BRYCHIUS HORNII (20665)	1 - 3	0.	0.	6.	6.
HYDRACARINA					
LEBERTIIDAE					
LEBERTIA SP. (21410)	1 - 3	0.	1.	0.	1.
AMPHIPODA					
TALITRIDAE					
HYALELLA AZTECA (41060)	1 - 3	0.	0.	3.	3.
OLIGOCHAETA					
-ALL- (59010)	1 - 3	0.	0.	2.	2.

TOTAL FOR 28 SPECIES BY REPLICATE: 1 - 3 15. 155. 531.

TOTAL FOR 3 REPLICATES, 28 SPECIES: 701.

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 8, 1980
STATION: RACETRACK TURNOFF, @ CLARK FORK, D.S. SED. PONDS (025) SUBSTATION: 221
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
EPHEMEROPTERA					
BAETIDAE					
BAETIS SPP. (1230)	1 - 3	43.	485.	1259.	1787.
PLECOPTERA					
PERLODIDAE					
ISOPERLA SPP. (3810)	1 - 3	3.	12.	38.	53.
PTERONARCYIDAE					
PTERONARCELLA BADIA (4510)	1 - 3	0.	0.	1.	1.
TRICHOPTERA					
-ALL- (8500)	1 - 3	0.	33.	8.	41.
HYDROPSYCHIDAE					
HYDROPSYCHE SPP. (8560)	1 - 3	1.	27.	198.	226.
CHEUMATOPSYCHE SPP. (6630)	1 - 3	0.	3.	7.	10.
LEPTOCERIDAE					
-ALL- (7200)	1 - 3	0.	8.	1.	9.
BRACHYCENTRIDAE					
BRACHYCENTRUS SP. (7410)	1 - 3	0.	2.	1.	3.
HYDROPTILIDAE					
-ALL- (7700)	1 - 3	0.	194.	143.	337.
HYDROPTILA SP. (7710)	1 - 3	0.	3.	1.	4.
HELICOPSYCHIDAE					
HELICOPSYCHE BOREALIS (8201)	1 - 3	0.	2.	0.	2.
LIMNEPHILIDAE					
ONOCOSMOECUS SP. (9580)	1 - 3	0.	4.	0.	4.
DIPTERA					
CHIRONOMIDAE					
-ALL- (10510)	1 - 3	2.	43.	78.	123.
CHIRONOMIDAE, S-FAMILY TANYPODINAE					
-ALL- (10610)	1 - 3	3.	5.	36.	44.
CHIRONOMIDAE, S-FAMILY-CHIRONOMINAE					
-ALL- (12110)	1 - 3	1.	0.	4.	5.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	1.	374.	165.	540.
SIMULIIDAE					
-ALL- (17510)	1 - 3	0.	6.	21.	27.

(Continued)

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02)
STATION: RACETRACK TURNOFF, S CLARK FORK, D.S. SED. PONDS (025) DATE: AUGUST 8, 1980
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6) SUBSTATION: 221
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
DIPTERA					
SIMULIIDAE					
SIMULIUM SP. (17530)	1 - 3	2.	10.	223.	235.
EMPIDIDAE					
-ALL- (18210)	1 - 3	1.	1.	0.	2.
TIPULIDAE					
HEXATOMA SP. (18360)	1 - 3	0.	14.	11.	25.
TIPULA SP. (18410)	1 - 3	0.	1.	2.	3.
ANTOCHA SP. (18450)	1 - 3	0.	2.	3.	5.
RHAGIONIDAE					
ATHERIX VARIEGATA (18710)	1 - 3	0.	3.	0.	3.
COLEOPTERA					
ELMIDAE					
ZAITZEVIA PARVULA (19770)	1 - 3	0.	2.	0.	2.
OPTIOSERVUS QUADRIMACULATUS (19930)	1 - 3	1.	135.	70.	206.
NARPUS CONCOLOR (20010)	1 - 3	0.	0.	1.	1.
CLEPTELMIS SP. (20110)	1 - 3	0.	1.	0.	1.
CLEPTELMIS ADDENDA (20111)	1 - 3	0.	1.	0.	1.
DYTISCIDAE					
LIODESSUS/OREODYTES SP. (20485)	1 - 3	0.	15.	3.	18.
-ALL- (20490)	1 - 3	0.	0.	2.	2.
HYDRACARINA					
LEBERTIIDAE					
LEBERTIA SP. (21410)	1 - 3	0.	1.	0.	1.

TOTAL FOR 31 SPECIES BY REPLICATE: 1 - 3 58. 1387. 2276.

TOTAL FOR 3 REPLICATES, 31 SPECIES: 3721.

APPENDIX C

PERIPHYTON CENSUS DATA

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 9, 1980
STATION: GREGSON HOT SPRINGS, SILVER BOW CREEK U.S. SED. PONDS (026) SUBSTATION: 221
SAMPLER TYPE: UNIT AREA PERIPHYTON SCRAPE (30)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (80)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
CHLOROCOCCALES					
SCENEDESMUS OBLIQUUS (16890)	1 - 3	2321.	564.	1026.	3911.
ULOTRICHALES					
HORMIDIUM SPP. (21750)	1 - 3	199.	902.	69.	1170.
CHAETOPHORALES					
STIGEOCLONIUM SPP. (24000)	1 - 3	265.	13649.	17100.	31014.
CRYPTOPHYTA					
CRYPTOMONADACEAE					
RHODOMONAS MINUTA VAR. NANNOPLANCTICA (48420)	1 - 3	133.	0.	0.	133.
CHRYSOPHYTA					
CHROMULINALES					
PHAEODERMATIUM RIVULARE (55630)	1 - 3	304317.	136150.	78523.	518990.
BACILLARIOPHYCEAE					
CENTRALES					
MELOSIRA VARIANS (63870)	1 - 3	60.	18.	55.	133.
CYCLOTELLA MENEGHINIANA (64110)	1 - 3	60.	18.	55.	133.
FRAGILARIACEAE					
MERIDION CIRCULARE VAR. CONSTRICTUM (70350)	1 - 3	30.	9.	27.	67.
FRAGILARIA LEPTOSTAURON (70820)	1 - 3	30.	9.	27.	67.
HANNAEA ARCUS (73110)	1 - 3	30.	9.	27.	67.
ACHNANTHACEAE					
ACHNANTHES MINUTISSIMA (74600)	1 - 3	751.	230.	329.	1311.
COCCONEIS PLACENTULA VAR. LINEATA (74850)	1 - 3	30.	9.	27.	67.
NAVICULACEAE					
NAVICULA ARVENSIS (77530)	1 - 3	30799.	9450.	28095.	68344.
GOMPHONEMACEAE					
GOMPHONEMA PARVULUM (80510)	1 - 3	60.	18.	55.	133.
CYMBELLACEAE					
CYMBELLA MINUTA VAR. SILESIACA (81520)	1 - 3	60.	18.	55.	133.
EPITHEMIACEAE					
RHOPALODIA GIBBA (82510)	1 - 3	30.	9.	27.	67.
NITZSCHIACEAE					
NITZSCHIA FRUSTULUM VAR. PERPUSILLA (84030)	1 - 3	30.	9.	27.	67.
NITZSCHIA PALEA (84050)	1 - 3	60.	18.	55.	133.

(Continued)

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 7, 1980
STATION: ANACONDA RD. AT CRACKERVILLE BRIDGE U.S. SEO. PONDS (024) SUBSTATION: 221
SAMPLER TYPE: UNIT AREA PERIPHYTON SCRAPE (30)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
BACILLARIOPHYCEAE					
NITZSCHIACEAE					
NITZSCHIA ACICULARIS (84010)	1 - 3	11.	7.	6.	23.
NITZSCHIA DISSIPATA (84020)	1 - 3	11.	7.	6.	23.
NITZSCHIA PALEA (84050)	1 - 3	32.	20.	19.	70.
SURIRELLACEAE					
SURIRELLA ANGUSTATA (85210)	1 - 3	85.	53.	50.	187.
SURIRELLA OVATA (85230)	1 - 3	43.	26.	25.	94.
CYANOPHYTA					
OSCILLATORIALES					
LYNGBYA AERUGINEO-CAERULEA (91530)	1 - 3	132.	0.	0.	132.
PHORMIDIUM SPP. (93000)	1 - 3	497.	712.	0.	1209.
MISC					
MONADS <10UM (99900)	1 - 3	132.	71.	33.	237.
SINGLE CELLS (99910)	1 - 3	596.	570.	828.	1993.

TOTAL FOR 30 SPECIES BY REPLICATE: 1 - 3 261348. 171239. 272937.

TOTAL FOR 3 REPLICATES, 30 SPECIES: 705524.

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 5, 1980
STATION: 1 MILE UPSTREAM OF ANACONDA FISH AND WILDLIFE PONDS (021) SUBSTATION: 131
SAMPLER TYPE: UNIT AREA PERIPHYTON SCRAPE (30)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (80)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
BACILLARIOPHYCEAE					
NAVICULACEAE					
NAVICULA VIRIDULA (77610)	1 - 3	7.	1.	12.	21.
NAVICULA DECUSSIS (77720)	1 - 3	4.	1.	6.	10.
GOMPHONEMACEAE					
GOMPHONEMA PARVULUM (80510)	1 - 3	4.	1.	6.	10.
CYMBELLACEAE					
CYMBELLA MINUTA VAR. SILESIACA (81520)	1 - 3	7.	1.	12.	21.
NITZSCHIACEAE					
NITZSCHIA ACICULARIS (84010)	1 - 3	4.	1.	6.	10.
NITZSCHIA DISSIPATA (84020)	1 - 3	11.	2.	19.	31.
NITZSCHIA HANTZSCHIANA (84040)	1 - 3	4.	1.	6.	10.
NITZSCHIA PALEA (84050)	1 - 3	4.	1.	6.	10.
NITZSCHIA LINEARIS (84090)	1 - 3	4.	1.	6.	10.
SURIRELLACEAE					
SURIRELLA ANGUSTATA (85210)	1 - 3	28.	5.	50.	83.
SURIRELLA OVATA (85230)	1 - 3	7.	1.	12.	21.
MISC					
MONADS <10UM (99900)	1 - 3	531.	0.	158.	689.
SINGLE CELLS (99910)	1 - 3	231.	75.	90.	396.

TOTAL FOR 39 SPECIES BY REPLICATE: 1 - 3 14254. 12955. 7968.

TOTAL FOR 3 REPLICATES, 39 SPECIES: 35177.

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 4, 1980
STATION: 1 MI DOWNSTREAM ANACONDA FISH AND WILDLIFE PONDS (023) SUBSTATION: 131
SAMPLER TYPE: UNIT AREA PERIPHYTON SCRAPE (30)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
CHLOROCOCCALES					
OOCYSTIS SPP. (15210)	1 - 3	0.	0.	5.	5.
SCENEDESMUS BIJUGA (18870)	1 - 3	247.	0.	20.	267.
SCENEDESMUS QUADRICAUDA (18880)	1 - 3	41.	0.	39.	80.
SCENEDESMUS OBLIQUUS (18890)	1 - 3	124.	0.	39.	163.
SCENEDESMUS DENTICULATUS (18900)	1 - 3	124.	43.	0.	167.
SCENEDESMUS ABUNDANS (18910)	1 - 3	41.	0.	0.	41.
SCENEDESMUS DIMORPHUS (18920)	1 - 3	0.	0.	98.	98.
PEDIASTRUM BORYANUM (20720)	1 - 3	0.	86.	79.	165.
PEDIASTRUM DUPLEX (20750)	1 - 3	659.	173.	627.	1459.
ZYGNEMATALES					
COSMARIUM SPP. (29320)	1 - 3	21.	0.	0.	21.
CRYPTOPHYTA					
CRYPTOMONADACEAE					
CRYPTOMONAS OVATA (47930)	1 - 3	0.	0.	5.	5.
RHODOMONAS MINUTA VAR. NANNOPLANCTICA (48420)	1 - 3	0.	0.	29.	29.
CHRYSOPHYTA					
CHROMULINALES					
PHAEODERMATIUM RIVULARE (55630)	1 - 3	0.	2084.	0.	2084.
BACILLARIOPHYCEAE					
CENTRALES					
CYCLOTELLA MENEGHINIANA (64110)	1 - 3	40.	23.	23.	86.
FRAGILARIACEAE					
FRAGILARIA VAUCHERIAE (70770)	1 - 3	227.	132.	129.	489.
FRAGILARIA LEPTOSTAURON (70820)	1 - 3	4.	2.	2.	9.
FRAGILARIA CROTONENSIS VAR. OREGONA (70860)	1 - 3	12.	7.	7.	26.
FRAGILARIA LEPTOSTAURON VAR. DUBIA (70870)	1 - 3	8.	5.	5.	17.
SYNEDRA RUMPENS (72120)	1 - 3	64.	37.	36.	137.
SYNEDRA ULNA VAR. OXYRHYNCHUS F. MEDIO-C (72200)	1 - 3	64.	37.	36.	137.
SYNEDRA ACUS (72240)	1 - 3	4.	2.	2.	9.
HANNAEA ARCUS (73110)	1 - 3	8.	5.	5.	17.
HANNAEA ARCUS VAR. AMPHIOXYS (73120)	1 - 3	8.	5.	5.	17.
ACHNANTHACEAE					
ACHNANTHES LANCEOLATA (74540)	1 - 3	8.	5.	5.	17.

(Continued)

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 4, 1980
STATION: 1 MI DOWNSTREAM ANACONDA FISH AND WILDLIFE PONDS (023) SUBSTATION: 131
SAMPLER TYPE: UNIT AREA PERIPHYTON SCRAPE (30)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (80)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
BACILLARIOPHYCEAE					
ACHNANTHACEAE					
ACHNANTHES MINUTISSIMA (74600)	1 - 3	275.	160.	156.	592.
COCCONEIS PLACENTULA VAR. LINEATA (74850)	1 - 3	44.	26.	25.	94.
NAVICULACEAE					
NAVICULA ARVENSIS (77530)	1 - 3	112.	65.	63.	240.
NAVICULA PUPULA (77590)	1 - 3	12.	7.	7.	28.
NAVICULA CAPITATA (77710)	1 - 3	8.	5.	5.	17.
GOMPHONEMACEAE					
GOMPHONEMA PARVULUM (80510)	1 - 3	8.	5.	5.	17.
GOMPHONEMA OLIVACEOIDES (80590)	1 - 3	4.	2.	2.	9.
CYMBELLACEAE					
AMPHORA PERPUSILLA (81030)	1 - 3	20.	12.	11.	43.
CYMBELLA MINUTA (81510)	1 - 3	8.	5.	5.	17.
CYMBELLA MINUTA VAR. SILESIACA (81520)	1 - 3	84.	49.	48.	180.
CYMBELLA SINUATA (81530)	1 - 3	44.	28.	25.	94.
CYMBELLA CISTULA (81560)	1 - 3	4.	2.	2.	9.
NITZSCHIACEAE					
NITZSCHIA ACICULARIS (84010)	1 - 3	4.	2.	2.	9.
NITZSCHIA DISSIPATA (84020)	1 - 3	24.	14.	14.	51.
NITZSCHIA FRUSTULUM VAR. PERPUSILLA (84030)	1 - 3	4.	2.	2.	9.
NITZSCHIA PALEA (84050)	1 - 3	2998.	1746.	1703.	6447.
NITZSCHIA LINEARIS (84090)	1 - 3	24.	28.	14.	65.
SURIRELLACEAE					
CYMATOPLEURA SOLEA (85110)	1 - 3	4.	2.	2.	9.
SURIRELLA ANGUSTATA (85210)	1 - 3	20.	12.	11.	43.
SURIRELLA OVATA (85230)	1 - 3	8.	5.	5.	17.
CYANOPHYTA					
OSCILLATORIALES					
LYNGBYA AERUGINEO-CAERULEA (91530)	1 - 3	0.	1080.	0.	1080.
PHORMIDIUM SPP. (93000)	1 - 3	20188.	23436.	14112.	57736.
MISC					
MONADS <10UM (99900)	1 - 3	21.	11.	0.	31.
SINGLE CELLS (99910)	1 - 3	52.	88.	37.	177.
TOTAL FOR 48 SPECIES BY REPLICATE:	1 - 3	25671.	29433.	17452.	
TOTAL FOR 3 REPLICATES, 48 SPECIES:		72556.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02) DATE: AUGUST 8, 1980
STATION: RACETRACK TURNOFF, S CLARK FORK, D.S. SED. PONDS (025) SUBSTATION: 221
SAMPLER TYPE: UNIT AREA PERIPHYTON SCRAPE (30)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
CHLOROCOCCALES					
SCENEDESMUS SPP. (18860)	1 - 3	80.	0.	0.	80.
SCENEDESMUS BIJUGA (18870)	1 - 3	0.	70.	0.	70.
SCENEDESMUS QUADRICAUDA (18880)	1 - 3	60.	158.	0.	219.
SCENEDESMUS OBLIQUUS (18890)	1 - 3	0.	0.	148.	148.
SCENEDESMUS ABUNDANS (18910)	1 - 3	0.	141.	148.	289.
PEDIASTRUM BORYANUM (20720)	1 - 3	0.	0.	297.	297.
PEDIASTRUM DUPLEX (20750)	1 - 3	242.	282.	297.	820.
ZYGNEMATALES					
COSMARIUM SPP. (29320)	1 - 3	15.	9.	0.	24.
CRYPTOPHYTA					
CRYPTOMONADACEAE					
RHODOMONAS MINUTA VAR. NANNOPLANCTICA (48420)	1 - 3	0.	35.	0.	35.
CHRYSOPHYTA					
CHROMULINALES					
PHAEODERMATIUM RIVULARE (55630)	1 - 3	242.	176.	0.	418.
BACILLARIOPHYCEAE					
CENTRALES					
CYCLOTELLA MENEGHINIANA (64110)	1 - 3	7.	8.	14.	30.
FRAGILARIACEAE					
FRAGILARIA VAUCHERIAE (70770)	1 - 3	122.	145.	257.	524.
FRAGILARIA LEPTOSTAURON (70820)	1 - 3	2.	2.	4.	7.
FRAGILARIA CAPUCINA VAR. MESOLEPTA (70840)	1 - 3	2.	2.	4.	7.
FRAGILARIA CROTONENSIS VAR. OREGONA (70860)	1 - 3	24.	29.	51.	103.
FRAGILARIA LEPTOSTAURON VAR. DUBIA (70870)	1 - 3	2.	2.	4.	7.
FRAGILARIA VAUCHERIAE VAR. CAPITELLATA (70880)	1 - 3	15.	18.	33.	66.
SYNEDRA RUMPENS (72120)	1 - 3	12.	14.	25.	52.
SYNEDRA ULNA VAR. OXYRHYNCHUS F. MEDIO-C (72200)	1 - 3	7.	8.	14.	30.
HANNAEA ARCUS (73110)	1 - 3	2.	2.	4.	7.
ACHNANTHACEAE					
ACHNANTHES LANCEOLATA (74540)	1 - 3	3.	4.	7.	15.
ACHNANTHES LINEARIS (74570)	1 - 3	34.	41.	72.	148.
ACHNANTHES MINUTISSIMA (74600)	1 - 3	777.	925.	1639.	3341.
COCCONEIS PLACENTULA VAR. LINEATA (74850)	1 - 3	3.	4.	7.	15.

(Continued)

PROJECT: TOXIC METALS PROJECT (TM) AREA: SILVER BOW CREEK, MONTANA (02)
STATION: RACETRACK TURNOFF, S CLARK FORK, D.S. SED. PONDS (025) DATE: AUGUST 8, 1980
SAMPLER TYPE: UNIT AREA PERIPHYTON SCRAPE (30) SUBSTATION: 221
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
BACILLARIOPHYCEAE					
NAVICULACEAE					
NAVICULA ARVENSIS (77530)	1 - 3	24.	29.	51.	103.
NAVICULA SALINARUM VAR. INTERMEDIA (77580)	1 - 3	2.	2.	4.	7.
NAVICULA PUPULA (77590)	1 - 3	2.	2.	4.	7.
NAVICULA VIRIDULA (77610)	1 - 3	2.	2.	4.	7.
GOMPHONEMACEAE					
GOMPHONEMA PARVULUM (80510)	1 - 3	134.	159.	282.	575.
CYMBELLACEAE					
CYMBELLA MINUTA VAR. SILESIACA (81520)	1 - 3	29.	35.	62.	125.
CYMBELLA SINUATA (81530)	1 - 3	3.	4.	7.	15.
NITZSCHIACEAE					
NITZSCHIA DISSIPATA (84020)	1 - 3	10.	12.	22.	44.
NITZSCHIA FRUSTULUM VAR. PERPUSILLA (84030)	1 - 3	5.	6.	11.	22.
NITZSCHIA PALEA (84050)	1 - 3	412.	490.	869.	1770.
NITZSCHIA LINEARIS (84090)	1 - 3	9.	10.	18.	37.
SURIRELLACEAE					
SURIRELLA ANGUSTATA (85210)	1 - 3	9.	10.	18.	37.
SURIRELLA OVATA (85230)	1 - 3	19.	22.	40.	81.
CYANOPHYTA					
OSCILLATORIALES					
LYNGBYA AERUGINEO-CAERULEA (91530)	1 - 3	4153.	5544.	5194.	14891.
OSCILLATORIA SPP. (92000)	1 - 3	0.	0.	779.	779.
PHORMIDIUM SPP. (93000)	1 - 3	151.	2816.	371.	3338.
MISC.					
MONADS <10UM (99900)	1 - 3	0.	0.	37.	37.
SINGLE CELLS (99910)	1 - 3	30.	141.	297.	468.

TOTAL FOR 42 SPECIES BY REPLICATE: 1 - 3 6624. 11360. 11093.

TOTAL FOR 3 REPLICATES, 42 SPECIES: 29077.

APPENDIX D

TISSUE METAL ANALYSIS SUMMARY DATA

MEAN COPPER CONCENTRATIONS (μg/g), SILVER BOW CREEK AND CLARK FORK, MONTANA, IN VARIOUS FISH TISSUES. Means are based on three analytical replicates unless otherwise indicated.

Station	Eye	Brain	Gill	Muscle	Liver	Kidney
026	1.3	1.7	13.8	0.4K	135.6	6.4
	1.4	4.8	7.9	0.5K	163.3	
024	52.7	5.9	15.5	0.8K	119.2	5.2
021	8.4	6.4	53.2	1.8	-	-
027	0.3K*	7.1	4.6	0.3K	508.4	12.8
	3.2	4.0	18.2	ND		
023	0.8	5.1	4.5	ND	M	21.3
	6.0	9.4	10.8	0.3K	M	52.9
	10.5	8.1	122.3	ND	M	43.1
	2.9	4.9	18.7	1.0	873.4M	128.5
	4.1	6.0	13.1	0.4	1019.4M	28.7
025	2.3	5.2	19.1	0.4K	M	4.7
	2.9	6.6	17.2	0.4K	M	38.3
	8.3	4.1	17.4	1.1	M	16.6

*Two replicates only
K=One or more replicates below instrument detection limits
M=One or more replicates in excess of instrument detection limits
ND=Not detectable

MEAN ZINC CONCENTRATIONS (µg/g), SILVER BOW CREEK AND CLARK FORK, MONTANA, IN VARIOUS FISH TISSUES. Means are based on three analytical replicates unless otherwise indicated.

Station	Eye	Brain	Gill	Muscle	Liver	Kidney
026	104.2	105.6	134.4	28.9	189.0	62.2
	209.8	151.4	136.8	33.5	144.3	
024	454.8	192.6	224.8	46.4	108.5	86.3
021	482.6	223.7	288.4	41.5	-	-
027	158.7*	118.5	711.7	24.8	160.7	76.0
	411.7	162.3	244.1	34.5		
023	310.1	159.1	230.9	138.4	285.0	196.0
	195.7	237.2	423.0	27.0	344.3	226.0
	827.3	259.8	401.0	27.2	178.5	203.9
	267.2	243.2	368.0	38.9	312.9	138.3
	198.9	287.0	467.2	28.9	367.1	97.7
025	728.4	197.7	252.9	20.3	263.6	148.1
	598.8	305.0	416.3	22.8	371.9	96.4
	379.0	564.3	476.5	51.4	394.3	128.7

*Two replicates only.

MEAN CADMIUM CONCENTRATIONS (μg/g), SILVER BOW CREEK AND CLARK FORK, MONTANA IN VARIOUS PLANT TISSUES. Means are based on three analytical replicates unless otherwise indicated.

Station	Roots	Leaves & Stems	Whole Plant	Station	Roots	Leaves & Stems	Whole Plant
026	ND**	ND	-	023	-	-	6.8
	13.5	ND*					ND**
		6.0					ND*
		6.8K					3.9K
		9.9					5.9K*
		ND**					5.0K
							6.7K
024	-	10.3	24.7				
			20.5	025	16.3	6.4	-
			17.1		7.6K	6.8	
			7.3K		ND**	5.5	
			10.6		14.8	9.4K	
					17.0	5.0K	
021	18.8	6.4	-		11.6	5.6K	
	6.9	6.4			8.9	5.3K	
	30.3	7.0					
	14.5	8.2					
	ND	3.9K					
	5.0K	ND					
	ND	ND**					
	ND	ND					
	ND	4.6					
	ND	49.K					

*Two replicates only.
**One replicate only
ND=Not detectable
K=One or more replicates less than instrumentation detection limits.

MEAN CHROMIUM CONCENTRATIONS (μg/g), SILVER BOW CREEK AND CLARK FORK, MONTANA, IN VARIOUS PLANT TISSUES. Means are based on three analytical replicates unless otherwise indicated.

Station	Roots	Leaves & Stems	Whole Plant
026	21.1	1.4	-
	18.4	2.4	
	15.4	7.5	
	9.7	5.2	
	40.6	9.9	
		5.0	
		13.2	
024	20.9M	11.1	6.8
	9.7	14.4	6.2
	11.7	5.4	5.5
			4.7
			17.2
			5.4
			7.5
021	4.1	0.4*	-
	1.6	ND**	
	7.1		
	1.4		
	2.4		
	0.7K		
	16.8		
	10.7		
	10.8		
	17.8		
	24.3		
	15.4		
023	-	-	12.3
			8.1
			3.5
			5.9
			24.1
			12.5
			1.4K*
			3.3
			1.4
			1.9*
			3.1
025	2.1	0.7*	-
	5.8	ND**	
	8.4		
	2.1		
	2.7*		
	2.4		
	6.1		

*Two replicates only.
**One replicate only.
ND=Not detectable.
K=One or more replicates less than instrumentation detection limits.
M=One or more replicates greater than instrumentation detection limits.

MEAN ZINC CONCENTRATIONS (µg/g), SILVER BOW CREEK AND CLARK FORK, MONTANA, IN VARIOUS PLANT TISSUES. Means are based on three analytical replicates unless otherwise indicated.

Station	Roots	Leaves & Stems	Whole Plant
026	2097.8	513.0	-
	1905.1	662.9	
	1748.3	1587.2	
	2285.1	1612.7	
	2235.1	1655.9	
		1379.4	
		1580.0	
024	2575.8	2249.4	1328.0
	2202.2	2949.1	1351.5
	2698.0	1392.4	1663.5
			1713.5
			1946.7
			1159.2
			1014.7
021	1282.1	196.5	-
	703.0	133.6	
	852.9	95.8	
	540.8	124.7	
	1015.5	269.8	
	996.5	242.3	
	2830.5	265.8	
	2261.7	166.6	
	1712.0	113.6	
	1428.1	110.3	
	1434.5	73.8	
	1113.6	120.2	
023	-	-	718.7
			722.4
			1099.1
			958.0
			560.0
			845.0
			553.1
			322.1
			384.7
			210.9
			328.4
			426.5
025	530.2	94.6	-
	719.7	92.5	
	706.3	89.6	
	534.1	281.1	
	815.4	147.8	
	734.2	158.6	
	1076.2	240.1	

MEAN COPPER CONCENTRATIONS (µg/g), SILVER BOW CREEK AND CLARK FORK, MONTANA, IN VARIOUS PLANT TISSUES. Means are based on three analytical replicates unless otherwise indicated.

Station	Roots	Leaves & Stems	Whole Plant
026	M	1277.6M	-
	M	M	
	M	M	
	M	M	
	M	M	
		M	
		M	
024	M	M	M
	M	M	M
	M	M	M
			M
			M
			M
			M
021	M	1354.3M	-
	M	751.2M	
	M	662.9	
	1088.8M	611.7	
	M	853.2	
	M	687.4	
	M	631.3	
	M	386.0	
	M	169.0	
	M	326.2	
	M	282.2	
	M	736.1	

Station	Roots	Leaves & Stems	Whole Plant
023	-	-	M
			M
			M
			M
			M
			M
			475.8
			216.4
			511.6M
			313.7
			620.6
			879.0
025	1032.0M	308.4	-
	M	241.0	
	M	298.6	
	1152.7M	593.4M	
	M	556.2	
	M	381.0	
	M	507.3	

M=One or more replicates in excess of instrumentation detection limits.

APPENDIX E

SUMMARIZED BIOASSAY RESULTS: DULUTH

COMPARISON OF FOUR TOXIC RESPONSES TO 30 AMBIENT WATER SAMPLES (Sample numbers relate to stations from 15 rivers sampled during the 1980 toxic metals project.)

Sample Number	Daphnia Toxicity	Enzyme Inhibition	Fish Ventilation Index	Algal Toxicity
011				
013	+	+	+	+
021	+	+		+
023		+		
034				
035	+	+		+
042		+		
045		+	+	
051				
054				+
061		+		
066		+		+
073		+	ND*	+
074		+	ND	
081	+			+
082	+	+	+	+
092		+	+	
094	+	+	+	+
102	+		+	
103	+		+	+
111				
114				
121			+	
122			+	+
132				
133	+		+	+
142	+		ND**	+
143	+		ND**	+
161		+		
162				

+ Positive response indicated.
* No data.
** Stress evident but unable to quantify.